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LEGAL PERSONHOOD OF ARTIFICIAL INTELLIGENCE

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Dedication

Oh God, Even my God my High Tower, my refuge, my redemeer, my only source of hope. This and many more is for you Oh God of the mighty universe.

Abstract

With the rise of AI, artistic creation of content is no longer a purely human enterprise. Currently works made by AI are considered to be computer assisted or aided works and copyright/patent right is vested in the human being who uses Al as a tool. However, questions have arisen as who owns the copyright/patent right in AI-generated works where there is no human input. Is it the inventor of the AI? The owner of the AI (Who may not be the inventor)? Or might the AI be given a certain degree of legal subject status and thus have its own rights?

Section 4 of the Copyrights and Neighbouring Rights Act, 2006[1] provides that the author of any work specified in section 5 shall have a right of protection of the work, where work is original and is reduced to material form in whatever method irrespective of quality of the work or the purpose for which it is created. Section 17(1) of the Industrial Property Act 2014[2] provides that the right to a patent belongs to the inventor. Section 17(2) of the same Act provides that where two or more persons have jointly made an invention the right to the patent belongs to them jointly. It remains unclear who the author or inventor of a work or invention by an AI will be.

AI may also lead to intellectual property disputes. AI must carry out "deep learning" and "deep thinking" through certain procedures. The AI might collect and store large amounts of information in which other people enjoy intellectual property protection. This creates potential copyright infringement issues. If an AI uses the acquired knowledge and information created by others to create a work, this may constitute plagiarism. This raises the question of who should bear the liability of this infringement- The inventor, the owner, or the AI itself. Although this question falls outside the scope of this research, it should be given priority when dealing with the implications of AI on intellectual property law. This topic has further raised other consequential issues. For example, even if AI were able to receive IP recognition, who would be able to commercialize the exclusive rights?

[1]Copyrights and Neighbouring Rights Act 2006

[2] Industrial property Act, 2014

Would there be any incentive to produce more innovations? Also, if ownership is given to the Al developer as a reward for effort and investment, why would the developer involved only during the input stage be rewarded for the final output stage as well? Finally, if the last option is for works produced by AI to fall into the public domain, why would developers put forth the mental and financial efforts to develop AI with vigour? As technological advances in Al continue to gather speed and threaten to disrupt intellectual property rights, this research looks at whether the law needs to be updated to make sure that the IP incentives to create and innovate that have worked in the past remain effective in the future. This research assesses Uganda's IP readiness for the era of Artificial Intelligence. The purpose of this book is to ascertain the status of works created by Artificial Intelligence under Uganda's current Intellectual Property legal regime and to assess Uganda's readiness for the era of Artificial intelligence.

Further to ascertain the terms under which works autonomously created by AI can be granted protection under Uganda's Intellectual Property legal framework, this coupled with identifying best practices from other jurisdictions that are being used to grant protection to works autonomously created by AI, hence providing recommendations on how Uganda's intellectual property law can be updated to incentivize AI-generated works in Uganda.

In light of WIPO consultations that commenced on 26th September 2019 to address Artificial intellectual property rights of AI, this research is timely. Most of the literature on whether AI can own intellectual property rights and how IP law can be amended to carter for AI is from developed countries like US & UK. There is an existing gap in literature from developing countries like Uganda, which, although they are not experiencing rapid technological developments in AI, will nevertheless be affected by AI's disruptiveness especially to their legal regime especially intellectual property. This research seeks to cover this gap by addressing how Uganda's IP law can be updated to carter for AI-generated works. This research will be done while taking into account Uganda's unique circumstances as a developing country.

Artificial Intelligence is expected to continue to grow and permeate all aspects of our lives. AI is already part of our lives in many ways for example, email spam filters, smart email categorization, plagiarism checkers, and so on.[3] AI has grown and developed to the point where it is able to create artistic works and inventions which qualify for intellectual property protection.

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[3] R.L. Adams, '10 Powerful Examples Of Artificial Intelligence In Use Today' Forbes 10 January 2017, hnps:/lwww.forbes.com/sitesirobertadamsl2017/01/10/10powerful-exarnples-of-anificial-intellie:ence-in-use- today/#4bge33e1420d accessed 24 January 2020.

CHAPTER ONE

Introduction

The production of artistic content is no longer solely a human endeavour with the development of Artificial intelligence (AI). Currently, AI-created works are regarded as computer-aided or assisted works, and the person using Al as a tool retains copyright and patent rights. **Who owns the copyright and patent rights for AI-generated works, where there is no human input, has, however, become an issue** Is it the man who created AI? Who is the AI's owner (who might not be the inventor)? Or may the AI be granted some legal subject status and thereby have its own rights? Artificial intelligence (AI) has arisen in the realm of creativity and innovation and is expected to become an integrated part of daily life in the near future. New AI technologies present exciting opportunities for developments in the creative arts, entertainment industries, as well as life enhancing inventions. However, of course, there are social, economic and ethical implications that need to be addressed and policy that needs to adjust accordingly. As such, WIPO undertook public consultation that seeks for measures to encourage technological innovation The study began in 2019 with The WIPO Technology Trends report, offering evidence-based projections to inform global policymakers on the future of AI. Subsequently, in September 2019, WIPO held a Conversation on IP and Al bringing together member states and other stakeholders to discuss the impact of Al on IP policy, with a view to collectively formulating the questions that policymakers need to ask. In December 2019, WIPO published its issues paper with a call for comments from the widest-possible global audience. Intellectual property has always had a symbiotic relationship with the development of new technology and in turn policy has needed to adapt to keep pace with the technology and cultural changes. AI technology has the potential to shake up the IP system, raising fundamental questions from inventorship and authorship to ownership and infringement. The advancement of AI technologies requires urgent attention from policy makers in order to ensure the effectiveness of the intellectual property regime, and to a greater extent to mitigate harmful social, economic and ethical implications.

Today, AI is much capable of generating and producing music. Even imaginative fiction writers have benefited from AI with highlights of reports, articles and even complete novels authored by AI.[4] The ABA journal's April issue's cover story declares that artificial intelligence is altering the way lawyers think, do business, and engage with clients. Artificial intelligence is defined as the theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages.[5] Ordinarily, Artificial intelligence can be referred to as **the simulation of human intelligence in machines**. The goals of artificial intelligence include learning, reasoning, and perception. (AI) is being used across different industries including finance and healthcare. In more general terms, AI refers to a broad field of science encompassing not only computer science but also psychology, philosophy, linguistics and other areas. AI is concerned with getting computers to do tasks that would normally require human intelligence. Having said that, there are many points of view on AI and many definitions exist. Below, some definitions highlight its key characteristics.

Some general definitions

"Artificial intelligence is a computerised system that exhibits behaviour that is commonly thought of as requiring intelligence."[6]

[44] Brian Merchant, 'When an A Goes Full Jack Kerouac' The Atlantic October 2018, <https:llwww.tbeatlantic.com/technology/arcbive/20 18/] 0/automated-on-the-roadl5713451> accessed 2] August 2019; Steven Poole, 'The rise of robot authors: is the writing on the wall for human novelists?' The Guardian 25 March 20 19,<htt;ps:l/www.theguardian.comlbooks/20 19/mar/25/tbe-rise-of-robot-authors- is-the-writing-on-the-wall- for-human-novelists> accessed 21 August 2019.

[5]The Oxford English Dictionary, Artificial Intelligence' https: l/en.oxforddictionaries.com/definition/artificial intelligence accessed 1 December 2016.

[6]Preparing for the Future of Artificial Intelligence, NSTC, 2016

"Artificial Intelligence is the science of making machines do things that would require intelligence if done by man."[7]

The founding father of AI, Alan Turing, defines this discipline as:

"AI is the science and engineering of making intelligent machines, especially intelligent computer programs."[8]

In these definitions, the concept of intelligence refers to some kind of ability to plan, reason and learn, sense and build some kind of perception of knowledge and communicate in natural language.

WIPO defines AI primarily as learning systems; that is, machines that can become better at a task typically performed by humans with limited or no human intervention.[9] Once considered a remote possibility reserved for science fiction, Artificial inte1ligence has advanced enough to approach a technological tipping point of generating ground breaking effects on humanity and is likely to leave no stratum of society untouched.[10] Many activities which could only be done by humans such as playing chess, reading hand writing are now routinely done by machines. AI is fast becoming part of our everyday lives, changing how we work, shop, travel and interact with each other. Yet we are only at the beginning of discovering the many ways in which AI will have an impact on business, society but also in the legal field. One legal field where Artificial intelligence is creating legal uncertainty is Intellectual property.

COMPUTER GENERATED POEM

[7] Raphael, B. 1976. The thinking computer. San Francisco, CA: W.H. Freeman

[8] http://www-formal.stanford.edu/jmc/whatisai/node1.html

9 WTPO (20)9), WIPO Technology Trends2019: Artificial Intelligence, Geneva: World intellectual Property Organisation, 19.

[10] World Economic Forum Artificial Intelligence, committed to improving the stale of the world; Artificial Intelligence Collides with Patent law (White paper, REF 160418 - case 00048540, 2018).4.

"he was silent/or a long moment.

he was silent for a moment.

it was quiet for a moment.

was dark and cold.

there was a pause.

it was my turn:"[11]

From the preceding poem, only the beginning and ending sentences were written by humans and in between then are the four that were generated by Google's Artificial Intelligence AI Projects in May, 2016.[12] More than 11,000 unpublished books had been fed to the AI by the researchers. They then applied the Recurrent Neural Network Language Model (RNNLM), which constructs sentences one word at a time by analysing the words that came before it.

Having fed the system with the first and last sentences, they then asked the system to fill in the gaps. The results were grammatically acceptable, followed a theme and ably corresponded with the first and last sentences and the publication of such findings sparked wide spread interest.

On 19th May 2017, the "Sunshine Lost Glass Window" was published by Microsoft's AI Microsoft Xiao Bing. This was a collection of 139 poems for which the AI had to analyse and review 519 modern-day poets and practice approximately 10000 times in order to come up with the compilation."[13]

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[11] Samuel R. Bowman et ai, 'Generating Sentences from a Continuous Space' Google lnc, May 2016, <https:llarxiv.org/pdf/1511.06349.pdt> accessed 21 August 2019.

[12] *Ibid.*

[13] "Ouyangsbaoxia, 'Microsoft Xiaobing for five years' *Technology Info,* 26 August, 2019, <https://technology- info.netlindex.phpI20 19/08/26/microsoft-xiaobing-for-five-years!> accessed 21 August 2019

With due advancements, the AI is now able to generate and compose music. For this reason, companies such as Google and IBM have developed AI systems that can scrutinise already existing songs and manipulate them to create their own. Juke deck and Amper Music have also developed systems which can be used to create whole tracks in a matter of seconds. This is achieved by carefully choosing tempo, style and mood.[14]

The AI has also been employed by authors of creative fiction. This is highlighted by Reports of articles and even entire novels written by AI.[15] The cover story of the April issue of the ABA journal proclaims that Artificial intelligence is changing the way lawyers think, the way they do business, the way they interact with clients. The Article further states that Artificial Intelligence is the next great hope that will revolutionize the legal profession.[16] Also, recommendations have been made those lawyers make use of the latest technology to have a paperless office for efficiency and conservation of resources.[17] There is therefore little doubt that AI has revolutionary implications for the creative industry all across the globe. AI is primarily defined by WIPO as learning systems; that is, machines that are capable

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[14] Alex Marshall, 'Is music about to have its first Al No.1?' BBC News, 28th february 2018, <bnps:llwww.bbc.co.uklmusic/articles/Oc3dc8f7-4853-4379-b0d5-62175d33d557> accessed 21 August 2019; Alex Marshall, 'From Jingles to Pop Hits, A.I. Is Music to Some Ears' New York Times, 22 January 201.7, <https:llwww.nytimes.com/2017/01/221arts/music/jukedeck-artificial-intelligence-songwriting.html> accessed 21

[15] Brian Merchant, 'When an A] Goes Full Jack Kerouac' The Atlantic October 2018, <https:llwww.tbeatlantic.com/technology/arcbive/20 18/] 0/automated-on-the-roadl5713451> accessed 2] August 2019; Steven Poole, 'The rise of robot authors: is the writing on the wall for human novelists?' The Guardian 25 March 20 19,<htt;ps:l/www.theguardian.comlbooks/20 19/mar/25/tbe-rise-of-robot-authors- is-the-writing-on-the-wall- for-human-novelists> accessed 21 August 2019.

[16] Legal Talk Network, 'How Artificial Intelligence will influence the future of legal practice' May 3 2016, <https:lllegaltalknetwork.comipodcastsllaw, technology-now/20 16/05/artificial- intelligence- wi 11i-nfluence- future- legal-practiCe!> accessed on 12 march 2020.

[17] Aleister Lovecraft, Satan's Advice to Young Lawyers, 2019.

of improving a task typically performed by humans with little or no human intervention.[18] This implies that the once sci-fi fantasy has advanced far enough to a point where it will have far-reaching effects on man and most likely to touch society evenly.[19] Many activities which could only be done by humans such as playing chess, reading hand writing are now routinely done by machines. AI is fast becoming part of our everyday lives, changing how we work, shop, travel and interact with each other. Yet we are only at the beginning of discovering the many ways in which AI will have an impact on business, society but also in the legal field. One legal field where Artificial intelligence is creating legal uncertainty is Intellectual property.

According to The World Intellectual Property Organisation, Intellectual property refers to products of the mind, inventions, literary and artistic works, any symbols, names, images and designs used in commerce.[20] Namely patents, copyright, trademarks and designs. The basic concept is that innovation must be rewarded[21] by allowing her to capitalize on her advent, earn her just rewards and hopefully stimulate her and others to make further inventions by granting an inventor a certain monopoly over what she has invented. If protection is not granted in this manner, there is danger of others reaping where they have not sown.[22]

Looking at the significant financial and mental investment that goes into the development of new products, allowing competitors to utilise these new products without having to necessarily compensate the inventors would greatly spur

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18 WTPO (20)9), WIPO Technology Trends2019: Artificial Intelligence, Geneva: World intellectual Property Organisation, 19.

[19] World Economic Forum Artificial Intelligence, Committed to improving the stale of the world; Artificial Intelligence Collides with Patent law (White paper, REF 160418 - case 00048540, 2018).4.

[20] Davies C, 'An evolutionary step in Intellectual Property Rights - artificial intelligence and intellectual property' (20 II) 27 Computer Law & Science Review, p. 605 and 606

[21] WIPO, W1PO Intellectual Property Handbook (2nd edition, WIPO, 2004), p.1

[22] Ibid, p. 605 and 606

creativity. This is because these areas provide intellectual property protection to works created by the mind. AI's entry into areas that have historically required human ingenuity raises many critical questions that must be addressed: for example, should AI generated creations be protected, and if so, who should be the inventor/author in AI generated creations. Intellectual property law remains an area at the cutting edge of technology and legislation in these areas needs to keep pace with advances in technology.[23]

Computers, coupled with human intelligence, have advanced to even make decisions on their own. This ability of a computer system to take decisions by itself came to be known as artificial intelligence, in common parlance. The term 'artificial intelligence' was formally coined by Mr. John McCarthy, a computer scientist at a conference in 1956.[24] According to him, it was the notion of a program, processing and acting on information, such that the result is parallel to how an intelligent person would respond in response to similar input.[25] It was this reliance and curiosity towards machines that AI projects were developed in a manner which allowed for the performance of tasks requiring human-like creativity.[26] However, a question arose whether the results being rendered by the machine are an outcome of its own intelligence, or algorithms and commands. To tackle the same, Sir Alan Turing proposed a test called the 'Turing test'.[27]

The test called for the users to converse with a machine/human in a text only format, and then suggest whether they believed they communicated with a human or a machine. As per Turing, an AI machine showed intelligence if the responses submitted by the same were indistinguishable from real human responses. While this test worked for a couple of years, its application was restricted only to speech

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[23] *Ibid*

[24] Prof. A Lakshminath & Dr. Mukund Sarda, Digital Revolution and Artificial Intelligence-Challenges to Legal Education and Legal Research, CNLU LJ (2) (2011-2012).

[25] Raquel Acosta, Artificial Intelligence and Authorship Rights, HARVARD JOURNAL OF LAW AND TECHNOLOGY (Feb. 17, 2012), http:// jolt.law.harvard.edu/digest/copyright/artificial-intelligence-andauthorship-rights.

[26] Mireille Bert-jaapkoops, et al., Bridging the Accountability Gap: Rights for New Entities in the Information Society?11 MINN. J.L. SCI. & TECH. 497, 549–50 (2010).

[27] Alan Turing, Computing Machinery and Intelligence, 59 MIND 236, 433– 60 (1950).

machines and certain quizzing purposes. The World Intellectual Property Organization (WIPO) identified the existence of AI and propounded three categories of AI, i.e., expert systems, perception systems, and natural-language systems.[28] Expert systems are the programs that solve problems in specialized fields of knowledge, such as, diagnosing medical conditions, recommending treatment, determining geological conditions, to name a few.[29] These systems are also used for creative purposes such as producing art and other such works. This system gathered legal attention when a computer authored work was denied copyright by the Registrar, on the grounds of indeterminate legal status of works created with the aid of computers.[30] This is an issue that still remains unresolved in many States. Perception systems are the systems that allow a computer to perceive the world with the sense of sight and hearing. This is used by topologists, word context experts, etc.[31] Lastly, a natural language program is meant to understand the meanings of words, requiring a dictionary database. What is noteworthy is, the system takes into consideration different grammatical and textual contexts, to provide a semantic analysis.[32] The use of these AI systems became so prevalent that, people wanted to procure protection on the outputs. However, the 1956 denial of copyright to a literary work, gave very bleak hopes to these aspirants. But the debate did not die down, and even reached national courts on grounds of its relevance to the field of IP, namely copyrights and patents.

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[28] A. Johnson-Laird, Neural Networks: The Next Intellectual Property Nightmare? 7 THE COMPUTER LAWYER 14 (March 1990).

[29] Id.

[30] Annemarie Birdy, Coding Creativity: Copyright and the Artificially Intelligent Author, STAN. TECH. L. RE. 5(26, 2012), https://web.law.columbia.edu/sites/default/files/microsites/kernochan/09.mat erials-Bridy.pdf

[31] R. KURZWEIL, THE AGE OF INTELLIGENT MACHINES, 272- 275 (MIT Press: 1990).

[32] id

CHAPTER TWO

Artificial Intelligence Can Be Viewed from a Variety of Perspectives.

Artificial intelligence is defined by the Oxford Dictionary as the theory and development of computer systems able to perform tasks normally requiring human intelligence.[33]

From the perspective of intelligence, artificial intelligence is making machines "intelligent" -- acting as we would expect people to act. The inability to distinguish computer responses from human responses is called the Turing test. Intelligence requires knowledge, Expert problem solving - restricting domain to allow including significant relevant knowledge

From a business perspective AI is a set of very powerful tools, and methodologies for using those tools to solve business problems.

From a programming perspective, AI includes the study of symbolic programming, problem solving, and search.

Since the earliest days of AI, its definition has focused on the ability to behave with the appearance of intelligence. Various forms of 'Turing test' declare machines as intelligent when humans cannot differentiate their actions from those of a human. Today's definitions of AI often include other requirements such as autonomy, and allow intelligence to be limited to specific domains. Rather than contributing to the

[33] The Oxford English Dictionary,. Artificial Intelligence' https:l/en.oxforddictionaries.com/definition/artificial intelligence accessed 1 December 2016.

proliferation of definitions[34] A Taiwanese computer scientist, Kai-Fu Lee[35] defines Artificial intelligence as "the elucidation of the human learning process, the quantification of the human thinking process, the explication of human behaviour, and the understanding of what makes intelligence possible. It is men's final step to understand themselves ..." As per Ronnerhed[36] in order to understand what AI is, one must first understand the definition of an algorithm and software. This basically is a process or set of rules to be followed in calculation or other problem-solving operations.[37] Software is a programme where several algorithms give instructions to perform a certain task.[38] She then goes ahead to define Artificial Intelligence as the simulation of human intelligence processes by machines, particularly computer systems. It ought to be put to note however that no single definition of AI is universally accepted by all practitioners. Artificial Intelligence is often decribed basing on its problem space, such as reason and logic, knowledge representation, natural language processing and perception or in terms of its many often-overlapping subfields, including expert systems, machine learning (ML), artificial neural networks, deep learning, and robotics.[39] AI has been classified into three groups by The World Intellectual Property Organization, i.e., **expert systems, perception systems, and natural-language systems.** Expert systems are the programs that address issues in specialized fields of knowledge, such as diagnosing medical conditions, recommending

[34] For a comprehensive review of definitions see Samoili, S. Et al, Defining artificial intelligence, European Commission, 2020.

[35] Kai Fu-Lee, *Al and Super powers, China, Silicon Valley and the New World Order,* (Houghton Mifflin Harcourt Publishing Company 2018)

[36] Jennifer Ronnerhed,. Artificial Intelligence Outsmarting human perception of what is patentable, An EU examination of the patentability of Artificial Intelligence' (Master thesis, Lund University 2018) 12.

[37] Oxford English Dictionary definition of algorithm, e-resource, Oxford University Press.

[38] *Ibid*

[39] World Economic Forum Artificial Intelligence, *Commiued 10 improving the state of the world; Artificial Intelligence Collides with Patent law* (White paper REF)60418 - case 00048540,2018) P5.

medication and determining geological conditions, to mention but a few.[40] The same systems are also used for creative purposes such as creation of artworks among others. a natural language program is meant to understand the meanings of words, requiring a dictionary database[41] and finally Perception systems are those that enable computers to perceive the world through hearing and sight.[42]

AI is also frequently classified basing on its level of intelligence, such as artificial general intelligence (AGJ), which is a theoretical form of AI which exhibits the most prevalent level of AI today that solves specific tasks. WIPO[43] defines AI as learning systems; that is, machines that can become better at a task typically performed by humans with limited or no human intervention. WIPO notes that AI at its core is simply powerful algorithms acquiring human-like capabilities, such as vision, speech and navigation. AI is moving forward to master more specialized tasks performed routinely by human experts.

The Terms Under Which Works Independently Created By Ai Can Be Granted Intellectual Property Protection

The question as to whether the "intelligent machines" can own rights to their creation is first a philosophical question rather than a legal question.

This is because the current position of the law grants IP protection to primarily to human works with only a few exceptions in country legislations like the UK Copyright Act that protects computer generated works. This area hereby addresses what other writers have had to say about intellectual property rights of machines.

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[40] A. Johnson-Laird, Neural Networks: The Next Intellectual Property Nightmare? The Computer Lawyer 14 (March 1990).

[41] Ibid.

[42] R. Kurzweil, 'The Age of Intelligent Machines', 272- 275 (MIT Press:1990).

[43] Ibid 19

Bird[44] proposes that employing "work for hire" doctrine in regards to AI generated works. In contrast however, according to Hristov[45] the application of the "work-for-hire is also not without faults. The author of the created work, according to this common law doctrine, is deemed not the person who has actually created it, but the person who has hired the de facto maker and commissioned the work. Applying this doctrine would simply imply that the AI shall take the place of the de facto creator, granting authorship to the programmer and avoiding the issue of endowing machines with rights. However, there is a drawback to the application of this doctrine; work-for-hire necessitates a contractual relationship between de-facto maker and beneficiary, which in the cases of creative logarithms, which lack the element of personhood, is not always possible.

According to Firth-Butterfield and Yoon Chae[46] the Creativity Machine developed by AI pioneer Stephen Thaler in 1994, was already capable of generating new ideas via the artificial neural networks. It is also known for generating an invention that was eventually issued on 15 May 1998as US Patent No. 5,852,815 making it the first-known patent to be issued to an AI- generated invention. However, Thaler listed himself as the sole inventor and did not disclose the Creativity Machine's involvement to the United States Patent and Trademark Office (USPTO).[47]This implied that the creator would take credit for any subsequent invention made by the AI. This however tends to ignore the autonomy exercised by the AI in developing its work.

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[44] Annemarie Birdy, 'Coding Creativity: Copyright and the Artificially Intelligent Author' (2012) Stanford
Technology Law Review.

[45] Hristov (n.48).

[46] Kay Firth-Butterfield and Yoon Chae, 'Robot inventors are on the rise. But are they welcomed by the patent system?' *World Economic Forum* (April 20 J 8) https://www.weforum.orglagendal20 J8/04/robot-inventors-on-rise- patent-system-USI accessed 24 January 2020.

[47] WorJd Economic Forum Artificial Intelligence, *Committed to improving the state of the world; Artificiallntelligence Collides with Paten/law* (White paper REF 160418 - case 00048540, 2018) 6

Perry and. Margoni[48] argue that for the programmer should be considered as the author in AI generated works. Their stand is primarily based on their proximity to the creative process and their understanding thereof. While the programmer is not the de-facto creator of the work, they understand how the algorithm works and are capable of explaining the creative process behind the output. Sorjamaa[49] explains that the programmer is entitled to the benefits, because he or she created the AI alogarithm However, Hristov[50] on the other hand explains that while these arguments are founded on sound logic and longstanding legal traditions like Lockean ethics and "sweat of the brow" doctrine, they are only applicable to cases where the logical link between the programmer and creative output of the program they wrote is visible.

The Invention Machine created by computer scientist John Koza created an invention that on 25 January 2005, resulted in the US patent No. 6,847,851. Only Koza and two other people were listed as inventor and the invention and machine's involvement was not disclosed to the USPTO during the patent's prosecution and implementation process. The fact that patents have already been granted AI inventions is remarkable for technological reasons, but it also raises concerns because it touches on unexplored patent law issues concerning patentability and inventor ship of AI-generated works.[51]

Abbott[52] believes that it will not be long before computers drive most innovations thereby, replacing the human mind. He claims that AI was not taken into account when writing the patent law or when contemplating upon the meaning of the inventor. However, Abbott proposes a compromise position whereby AI would

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48 Mark Perry and Thomas Margoni, 'From Music Tracks to Google Maps: Who Owns Computer-Generated Works?'
(2010) 16 Computer Law & Security Review 10

49 TuomasSorjamaa, 'Authorship and Copyright in the Age of Artificial Intelligence, 2016 Hanken School of Economics, Helsinki.

50 *Ibid 31*

51 Ibid

52 Ryan Abbott, 'Hall the Inventor: Big Data and Its Use by Artificial Intelligence' (19 February 2015) SSRN MIT Press, 1.

be granted the inventorship and the holder of the computer patent the ownership. Abbott separates inventorship and ownership because of differences between them. The creative mind behind the invention is what is referred to as the inventor. The recognition of the right to proprietary right is referred to as ownership. However, the owner does not necessarily match the inventor. Abbort's proposed compromise of regarding AI alone as the inventor has yet to be endorsed by other legal professionals.[53]

In agreement with Abbort, Ronnerhed[54] agrees that AI should be able to be the inventor. In her work, she also suggests that if that is too drastic, then Al should be able to be co-inventors with physical persons whilst ownership could be either a physical or a legal person. She claims that allowing AI to be categorized as a physical or legal person would solve the problem. This is especially relevant in cases of complex computational techniques like machine learning, it would be close to impossible where distinguishing the contributions of the inventors.[55] The same is true when AI and humans collaborate. The inability to trace back the individual input in the final product renders the applicability of joint creation inapplicable.[56] This approach examines the applicability of this subject in Uganda. On the contrary, Anne & Sven Hetmank[57] suggest that allowing AI to be classified as a physical or legal person would not be a good solution because it would not resolve the question of who could grant licenses or enforce the IP right in the event of infringement. An AI may not be able to institute a complaint or a lawsuit about infringement. In addition to that, they state that JP rights should be allocated in such way as to provide for an incentive to invest in the development of AI and that

[53] Jennifer Ronnerhed, 'Artificial Intelligence Outsmarting human perception of what is patentable, An EU Examination of the patentability of Artificial Intelligence' (Master thesis, Lund University 2018) 35.

[54] *Ibid*

[55] PetarHristov, 'Works Generated by Al - How Artificial Intelligence Challenges Our Perceptions of Authorship', (Master thesis, Tilburg University Law School 2017) 39

[56] Ibid

[57] Anne & Sven Hetmank, 'The Concept of authorship and inventorship under pressure: Does artificial intelligence shift paradigms?'20 197(14) Journal of Intellectual Property Law & Practice,577.

granting legal personality legal personality to AI itself wouldn't in any case achieve this goal.

According to Hristov[58] leaving AI generated works unprotected and in the public domain is the better way to go because it follows the natural logic of copyrights. The Public Domain is formed by works whose term of protection has expired, by works whose authors are unknown, by works that do not meet the criteria for protection.[59] While the authors of the works in the Public Domain may be known, the works themselves are not under copyright protection. Some authors like Sorjamaa are of the opinion that leaving AI-generated works unprotected will diminish the incentives to invest and develop AI technologies, ultimately leaving society worse off[60]. Hristov and other scholars[61] view Public Domain as a balancing counterweight to copyright's over-expansion as well as an important inspiration for human creativity. Furthermore, he asserts that leaving AI generated works in the public domain will serve as a valuable pool of inspiration, which creative individuals may use without fearing copyright infringements. Furthermore, he asserts that assigning authorship to the human in the equation may unjustifiably expand copyrights over works that were not created by them. Given the AI's potential for unlimited creation of works, it is easy to imagine a rapid and unbalanced growth in AI-generated copyright-protected works that will ultimately hinder free imitation and creation. Hristov counteracts the argument that exporting the output of creative Al in the public realm would deprive many related stakeholders of the reward they expect and deserve by making an assumption that today AI is created to challenge humanity's conceptions of

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[58] Petar Hristov, 'Works Generated by AI - How Artificial Intelligence ChaIJenges Our Perceptions of Authorship', (Master thesis, Tilburg University Law School 20 (7) 39

[59] Hristov (n.40).

[60] *Ibid*

[61] Clark Asay, 'A Case for the Public Domain', (2012) Ohio State Law Journal, chapter 4; Timothy Armstrong,
'Shrinking the Commons: Termination of Copyright Licenses and Transfers for the Benefit ofthe Public, 47 Harvard
Journal on Legislation (20 10):

creativity and intelligence, rather than to extract economic gains. On this note, the researcher in a thesis on Artificial intelligence[62] disagrees with the author's blanket assumption that is not well founded and ignores economic considerations behind utilization of AI to come up with AI generated works. Here she highlighted companies like Google, Tesla that employ AI for economic value. WU[63] argues regarding copyright that assigning authorship to AI is possible and permissible under specific circumstances; that the AI must produce works that are not anticipated, that there must be no human interaction ensuring the algorithm acts independently, that the AI has the ability to decide when to produce future works. By applying a matrix of human creativity to machine creativity, he implies, that machines can be deemed authors only when they become autonomous and self-aware on a human-like level. At this point, such a high standard seems hardly achievable. Ginsburg[64] makes the argument against the notion of machine authorship based on the lack of machine autonomy. This means that a machine needs to be able to autonomously decide when and how to exercise its rights as an owner, in order for machine authorship to be a feasible concept. The researcher does not agree with the requirement that autonomous machine must decide when and how to exercise its rights as an owner. The concept of machine learning requires that vast amounts of data be made available to the machine. That Ipso facto, means that an AI machine cannot decide when and how to exercise its authorship rights unless it is exposed to data. This high standard of autonomy makes it nearly impossible for machines to be able to acquire authorship rights in AI generated works.

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[62] ....

[63] 65Andrew J. Wu, 'From Video Games to AI: Assigning Copyright Ownership to Works Generated by Increasingly Sophisticated Computer Programs', AIPLA Quarterly Journal (1997).

[64] Jane C. Ginsburg, 'The Concept of Authorship in Comparative Copyright Law' for DePaul L. Rev. Symposium: "The Many Faces of Authorship", Columbia Law School (2003).

Samuelson, Birdy, Thomas Margoni[65] among other scholars have refuted arguments in favour granting authorship rights to the user of an algorithm. Such arguments are based on the idea that the user utilizes the machine as a tool in the process of expressing their own creativity. Today, when creative output can be mediated by a single click of a button tills concept is called into question by both common sense and by scholars. When the user's input can be reduced to a mere click of a button, it is hard to justify that it constitutes the creation of an original work or transmits the user's own creativity and individuality. The same logic was employed by the court in Nova Productions Ltd[66] Mazooma Games Ltd. The Court employed similar logic when assessing the users' contribution. While acknowledging the user's involvement to provoke and actuate the creative powers of the algorithm, the court found this involvement insufficient to invoke attribution of authorship and consequently ownership. The judge stated that the players contribution is not artistic in nature and he has contributed no artistic skill or labour of artistic kind. He has also not made any preparations required for the creation of the frame images. All he has done is to play the game". Another disadvantage of the user being granted copyright in the works created by Al is, in Samuelson's opinion, this concept's infeasibility due to doctrinal and policy reasons. Such allocation of authorship would undoubtedly diminish the incentives for programmers to create, as it would lead to the user practically "free-riding" on the programmer's skill and effort.[67]

While acknowledging that AI computers may be capable of exhibiting sufficient originality to qualify for copyright, Samuelson[68] believes that they would be denied

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[65] Pamela Samuelson, "Allocating Ownership Rights in Computer-Generated Works", U. Pitt. L. Rev 1185 (1985); Annemarie Birdy, "Coding Creativity: Copyright and the Artificially Intelligent Author" in Stanford Technology Law Review. issue 5 (2012); Mark Perry and Thomas Margoni, "From Music Tracks to Google Maps: Who Owns Computer-Generated Works?" in Computer Law & Security Review, issue 26 (2010)
[66] [2007] EWCA Civ 219, Royal Courts of Justice, Court of Appeal, London;
67 Hristov (n.60).

[68] sOPamela Samuelson, .Aallocating Ownership Rights in Computer Generated works' (1985) 47 *University of Pittsburgh Law Review 11851228.*

because Congress did not contemplate the grant of intellectual property rights to machines and have only ever allocated them to humans. She further supports this by referring to what is regarded as one of the primary reasons for the existence of intellectual property, that of incentive. The machine has no need for incentive to create and therefore is not deserving of the grant of the rights arising from its creation. However, Davies[69] submits that whilst incentive is a justification for the existence of intellectual property rights it is not a requirement for the generation of such rights.[70] This stems from the theory that economic incentives are the central underlying basis for intellectual property. Per this theory, intellectual property protections must be provided to creators in order to encourage them to producetheir works.

All of the above contributions by various authors on ownership of Intellectual property rights are timely in light of WIPO consultations that commenced on 26th September 2019 to address Artificial Intelligence and intellectual property rights.[71] However, the literature on whether AI can own intellectual property rights is largely from authors in developed countries like UK, US and China. Notably in January 2020 a court in Shenzhen, Guangdong province in China ruled that a work generated by AI qualified for copyright protection.[72] The Chinese tech giant, Tencent, successfully sued an online platform for copying an article written by Tencent's robot Dream writer without authorization. Notably though, Tencent was considered the copyright owner.

There is an undeniable gap in the literature from developing countries such as Uganda, which, while not experiencing rapid technological developments in AI,

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[69] Colin R. Davies, *An evolutionary step in intellectual Property rights - Artificial intelligence and intellectual property,* (Elsevier Ltd 20 I 1) 611.82*Ibid* 611.

[70] *Ibid 611*

[71] WIPO Conversation on Intellectual Property and Artificial Intelligence, <https:llwww.wipo.intlaboul- ip/en/artificial intelligence/news/20 19/news 0007.html.> accessed 23January, 2020

[72] Court rules Al-wrirten article bas copyright' EeNS 9 January 2020 http://www.ecns.cn/newsl2020-01-09/detail-ifzsgcrrn6562963.shtml accessed 6 Apri12020.

will nevertheless be affected by AT's disruptiveness particularly to their legal regime especially intellectual property. Law has historically been primarily reactive and, when it attempts to shape some technology after it has been solidified in the social, political, and economic spheres of society, control becomes more difficult, costly and time consuming[73]. The implementation of regulatory regime at this moment could have positive impacts and could avoid ineffectiveness of the law by anticipating rather than lagging behind technology. The current legal framework is not well suited to dealing with the disruptive nature of Artificial Intelligence. The inadequacy of the current laws creates legal gaps, which the above submission addresses in regards to assessment of Uganda's Intellectual Property framework

[73] Joao Paulo A, 'The regulation of Artificiallnteliigence', (Master Thesis, Ti Iburg University 2017)

CHAPTER THREE

Philosophy of Ai

While exploiting the power of the computer systems, the curiosity of human, led him to wonder, **"Can a machine think and behave like humans do?"** Thus, the development of AI started with the intention of creating similar intelligence in machines that we find and regard high in humans.

The intellectual property systems (IPS) around the world have developed with the purpose of promoting social welfare through the stimulation of innovation, research, and creativity. This, is known as the utilitarian theory of intellectual property law[74] This theory postulates that an author/inventor ought to be allowed a right to the benefit of his invention for some certain time as an encouragement to men to pursue ideas, which may produce utility. IP does this by granting the author or inventor exclusive rights over their output for a set period of time in exchange for them disseminating it. This facilitates him or her to recoup the costs incurred and he/she will be stimulated to invent more.[75]

The Intellectual Property system strikes the light balance between the interests of innovators and the wider public interest aimed at fostering an environment in which creativity and innovation can flourish.[76] The development of Intellectual Property law has been premised on the protection of works produced by the human mind. No consideration had been given to works produced by AI. AI systems are now able to successfully perform intellectual tasks that could be undertaken by the

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[74] Neil Wilkof, 'Theories of intellectual property: Is it worth the effort?' (2014) 9(4) *Journal of Intellectual Property Law & Practice 257*

[75] Annette Kur and Thomas Dreier, European Intellectual Property Law (Edward Edgar Publishing, 2013), p.9.

[76] World Intellectual Property Organization, WIPO *Intellectual Property Handbook: Policy, Law and Use,* WTPO publication No. 489 (E), (2008).

human brain as opposed to supervised learning where AI produces work anticipated by the programmer or inventor. Such works cannot logically be attributed to the inventor. Others have argued that granting intellectual property rights to AI machines does not promote the utilitarian foundation upon which intellectual property is based which is to incentivize innovation.[77] Alternatively, if AI is not granted Intellectual property rights in its AI generated work, the work could fall into public domain which does not promote investment in AI. These are questions that policy makers and TP experts must grapple with in order to ensure that the Intellectual property framework is not outdated, as a result of technological advancements in AI[78]. In reference to a one thesis on Artificial Intelligence[79],Ada Lovelace would have been AI's mother if it had had one![80]. best known for her collaboration with. Best known for work with Charles Babbage (considered as the father of the computer) on automatic calculating machines and the analytical engine, which was supposed to be the world's first programmable computer, Ada came to be known to be the world's first computer programmer[81]. The term computer was coined, at the time to refer to female secretarial workers who operated mechanical adding machines. Ada, ironically was the first to publish analgorithm, and to anticipate that machines were capable of doing much more than just performing calculations[82]. Despite this however, the literature on AI more commonly attributes this development to Alan Turing, who surfaced nearly a century after Lovelace,[83]. This is so due to a prediction Alan Turing made in his paper entitled, Computing Machinery and Intelligence,

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[77] *Ibid.*

[78] Un published thesis by ....

[80] Daryl Lim, 'AI & IP Innovation & Creativity in the Age of Accelerated Change', (2013) 52 Akron L. Rev. 813.

[81] Ibid 818

[82] Ibid 819

[83] Ibid

envisaging that a computer could evolve beyond performing human programmed tasks to become a thinking machine.[84]

In the paper, "can machines think", Turing argued that they could contradict with Ada Lovelace's conclusion that machines could only do what humans programmed them to do. Turing, in a 1950 article, he countered what he called "Lady Ada Lovelace's objection." Here he quotes where she stated: " ... The Analytical engine has no pretensions whatever to origin anything. It can do whatever we know how to order it perform"[85]. Turing argued that machines would eventually have the ability to think hence giving rise to the idea of Artificial intelligence.

In the 1950 paper, English mathematician Alan Turing introduced the concept of AI, " and during the Dartmouth Conference in 1956.[86] The American computer scientist John McCarthy coined the term "artificial intelligence". AI was established as an academic discipline and promising logic-based problem-solving approaches, enjoyed government funding[87]. However, between 1974- 1980, overly high expectations combined with limited AI programs capacities led to the first" AI winter", with reduced funding and interest in AI research[88]. Since then, AI has gone through mixed fortunes marked by a second "AI winter" that started with the sudden collapse of the specialized hardware industry in 1987[89] In 1993 - 2011, optimism about AI returned with the help of increased computational power and AI becomes data driven. Increase in the availability of data, connectivity and computational power enabled breakthroughs in machine learning, particularly in neural networks and deep learning, ushering in a new era of increased funding

[84] A point of view: Will Machines ever be able to think' BBC 18 0ctober 20 13, https: llwww.bbc.com/news/ma!?: azine- 24565995, accessed 27 February 2020.

[85] Ibid

[86]World Economic Forum Artificial *Intelligence, committed to improving the state of the world; Artificial Intelligence*
Collides with Patent law (Whitepaper 160418-case00048540, 2018).

[87]WIPO, *Biotechnology Trends 2019. Artificial Intelligence,* (2019) 19.

[88] *Ibid.*

[89] *Ibid.*

and optimism about AI potency.[90]. AI is becoming more popular nowadays. The general public's attitude has shifted in recent years which may have an indirect impact on legal and policy considerations. Deep Knowledge, a Japanese venture capital firm appointed Vital, an AI based robot to its board of directors in 2014. Furthermore, in October 2017, Saudi Arabia declared Sophia, an AI -powered social robot, making her the world's first AI citizen.[91] Such increased acceptance of AI as a self-sufficient "beings" or "citizens" can have a significant impact policy consideration regarding patent law issues, particularly on whether AI can be treated as an or "infringer" or "inventor."

The presence of AI has been observed in Uganda. The Artificial Intelligence and Data Science Research Group at Makerere University for example, specializes in the application of artificial intelligence and data science - to problems in the developing world[92] including methods from machine learning, computer vision to predictive analytics. Bowmans, a law firm, announced in 2018 that it had begun using AI to conduct its business in order to improve on its services. Now that AI is capable of autonomously generating innovations, WIPO has commenced consultations among member countries since 2019 to answer the question whether Intellectual Property ought to be updated to provide for rights in AI generated creations and who should be deemed their sole owner.

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[90] *Ibid*

[91]World Economic forum Artificial Intelligence; Committed *to improving the state of the world; Artificial Intelligence*
Collides with Patent law (White paper REF 160418- case00048540, 2018, 6

[92]<http://www.air.ug/.>

CHAPTER FOUR

What Is Intelligence?

The ability of a system to calculate, reason, perceive relationships and analogies, learn from experience, store and retrieve information from memory, solve problems, comprehend complex ideas, use natural language fluently, classify, generalize, and adapt new situations.

Artificial intelligence has entered into the sphere of creativity and ingenuity. Recent headlines refer to paintings produced by machines, music performed or composed by algorithms or drugs discovered by computer programs. This paper discusses the possible implications of the development and adoption of this new technology in the intellectual property framework and presents the opinions expressed by practitioners and legal scholars in recent publications.

'Artificial intelligence (AI) is a transformative technology, which is already revolutionising many areas of our lives. Unleashing the power of AI is a top priority in the plan to be the most pro-tech government ever'. Thus, opens modestly the consultation on Artificial Intelligence and Intellectual Property: Copyright and Patents, conducted by the UK Intellectual Property Office (IPO) between 29 October 2021 and 7 January 2022.1 The Consultation sought 'evidence and views' on three specific areas: Copyright protection for computer-generated works without a human author. These are currently protected in the UK for 50 years. But should they be protected at all and if so, how should they be protected? Licensing or exceptions to copyright for text and data mining (TDM), which is often significant in AI use and development. Patent protection for AI-devised inventions. Should we protect them and if so, how should they be protected?

As AI continues to emerge as a general-purpose technology with widespread applications throughout the economy and society, this poses fundamental questions that sit at the heart of the existing IP systems. Does AI innovation and creation need IP incentives? How should the value of human invention and creation be balanced against AI innovation and creation? Does the advent of AI require any changes to the existing IP frameworks? And do the existing IP systems need to be modified to provide balanced protection for machine created works and inventions, Al itself and the data Al relies on to operate.

"Products of the mind, innovations, literary and artistic works, any symbols, names, images, and patterns utilized in business are all considered to be intellectual property," according to the World Intellectual Property Organization.[93] Specifically, designs, trademarks, copyright, and patents. The fundamental tenet is that rewards must be given for invention.[94] Giving an inventor a certain amount of monopoly over what she has produced will enable her to profit from it, ensure that she receives proper compensation, and hopefully inspire other people to come up with more inventions. Inventions run the risk of being misused if protection is not provided in this way.

Globally, intellectual property systems (IPS) were created with the intention of advancing social welfare by encouraging research, innovation, and creative expression. The utilitarian philosophy of intellectual property law is referred to as this. According to this view, an author or inventor should be given the right to profit from their creation for a set period of time in order to encourage men to pursue ideas that could be useful. IP does this by giving the creator or inventor, in exchange for their dissemination of the work, exclusive rights over their output for a predetermined length of time. This helps him or her recover the money paid, and it will inspire them to come up with other inventions.

The Intellectual Property system strikes the light balance between the interests of innovators and the wider public interest aimed at fostering an environment in which creativity and innovation can flourish.[95] The development of Intellectual

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[93]Davies C, 'An evolutionary step in Intellectual Property Rights - artificial intelligence and intellectual property' (20 II) 27 Computer Law & Science Review, p. 605 and 606

[94]WIPO, W1PO Intellectual Property Handbook (2nd edition, WIPO, 2004), p.1

[95]World Intellectual Property Organization, WIPO Intellectual Property Handbook: Policy*, Law and Use,* WTPO publication No.489(E), (2008).

Property law has been premised on the protection of works produced by the human mind. No consideration had been given to works produced by AI. AI systems are now able to successfully perform intellectual tasks that could be undertaken by the human brain as opposed to supervised learning where AI produces work anticipated by the programmer or inventor. Such works cannot logically be attributed to the inventor. Others have argued that granting intellectual property rights to AI machines does not promote the utilitarian foundation upon which intellectual property is based which is to incentivize innovation.[96] Alternatively, if AI is not granted Intellectual property rights in its AI generated work, the work could fall into public domain which does not promote investment in AI. These are questions that policy makers and TP experts must grapple with in order to ensure that the Intellectual property framework is not outdated, as a result of technological advancements in AI.

Mind-made creations are protected under intellectual property. This raises the question of whether AI is capable of thinking up original ideas. Al-programs were primarily utilized as a simple tool or aid to assist people in producing works that are also known as Al-aided creations. Al-programs now create works without much, if any, creative input from humans at the moment the work is being produced. These pieces of art are known as AI-generated artwork. Instead of AI-assisted works, this research is primarily concerned with AI-generated works.

Current intellectual property laws are not well suited to deal with the issue of ownership of potential intangible assets autonomously created by artificial intelligence technology. Although a number of solutions are possible, the sensible and pragmatic approach is for ownership to sit with the person who commissioned the assets. The implications of the suggested ownership solution have to be carefully thought through, because it is inextricably linked with the question of who is accountable when fully autonomous AI causes accidents.

Intellectual property protects creations of the mind.[97] **This puts down the question whether AI has a mind to produce intellectual works.** Al-programs

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[96] *Ibid.*

[97] David I. Bainbridge, I n t e l l e c t u a l *Property,* (prentice Hall 2010)

were mainly used as a mere tool or aid to help humans create works also known as Al-aided creations.[98] Now, Al-programs create work in absence of any - or little - human intervention or creative input at the time of the creation of the work. These works are referred to as AI-generated works[99]. This research is focused on AI-generated creations as opposed to AI-aided works.

Allan Turing remarked that if a machine acts as intelligently as human being, then it is as intelligent as a human being. According to Max Tegmark, intelligence is the ability to accomplish complex goals. The growth of AI concepts like machine learning, deep learning and neural networks, is challenging the human-centric concept of the word "mind" as adapted in intellectual property law. This is because AI is able to autonomously generate creations using these concepts. Machine learning is a branch of AI that aims to give machines the ability to learn a task without pre-existing code.[100] Deep learning helps machine to learn more than a specific task. Deep learning is a subset of machine learning in which artificial neural networks adapt and learn from vast amounts of data.[101] Deep learning is often made possible by artificial neural networks, which imitate neurons or brain cells. Neural network refers to a learning process inspired by the neural structures of the brain.[102] It is a connected framework of mainly functions (neurons) working together to process multiple data inputs. The network is generally organized in successive layers of functions, each layer using the output of the previous one as in put.[103]

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[98] A Michel, "AI-generated creations: Challenging the traditional concept of Copyright" (2018) http://arno.uvt.nI/show.cgi?fid=148002

[99] *Ibid 14*

[100] RBR Staff, 'What is Artificial Intelligence? Understanding 3 Basic Al concepts' *Robotic business review.* April 19[1h] 2018, https: l!www.roboricsbusinessreview.comJail3-basic-ai-concepts-explain-artificial-intelligence! accessed 19 January, 2020.

[101] *Ibid*

[102] *Ibid*

[103] WIPO, *WIPO Technology Trends2019: Artificial Intelligence, World* Intellectual Property Organisation, (20 I9) 146.

The intellectual property law worldwide in its current state de-incentivizes AI generated innovations because it only grants protection to human generated works. Therefore, intellectual property law needs to be updated so that it can fulfil the objective on which it is founded[104].

Economic, Philosophical and Sociological Questions on artificial intelligence.

Creative AI algorithms pose interesting and valuable humanities and social science questions that remain under explored. In this area, the economic questions are highly pressing. Proponents of recognising AI inventors for purposes of patent law sometimes claim that such recognition will have a beneficial effect on innovation incentives. On the other hand, is there any evidence of a market failure in relation to AI related outputs? The claim can equally be made that creative AI algorithms reduce the costs of innovation and creativity. If so, the public goods market failure that underpins the justification of IP rights may be becoming less pronounced. Which effect will dominate? Will patents encourage greater innovation? Or is the real effect of creative AI algorithms to weaken the case for the patent system altogether as the costs of innovation fall? Historical economic case studies may reveal important information in this regard. While developments in machine learning pose new questions, IP lawyers have struggled to accommodate computer generated outputs for over fifty years. In some cases, studying the attempts to regulate such outputs may prove valuable. To illustrate, in the Copyright, Designs and Patents Act 1988 (UK), the UK Parliament adopted a unique provision for 'computer-generated works. Section 9(3) of the legislation provides protection to works that are produced without a human author. The section was subsequently adopted in various other (common law) jurisdictions. To date, however, there has been no attempt to evaluate the effect of that clause. Did the clause have any noticeable effect on businesses? Did it lead to enhanced creativity? Before adopting new provisions to IP legislation, lawmakers might consider the effects (if any) that previous legal changes have had in this field. Businesses did not appear to notice when s9(3) was added to the Copyright, Designs, and Patents Act 1988 (UK).

[104] Un published thesis by..................

Enrico Bonadio Creative AI algorithms also pose philosophical questions about the value of human creativity. Extant philosophical literature has focused significantly on the conceptual question of whether machines can be 'inventors' or 'authors', properly so called. But there remains interesting space to explore how AI is changing our values. In a world where AI can produce all our hit pop songs, is human creativity still uniquely valuable? And, if so, is it so valuable that it is worth encouraging such human creativity through IP rights, with all the deadweight, enforcement, and administrative costs that are associated with such a policy mechanism? For some, the cost of IP rights may be enough to make encouraging human creativity no longer attractive. In a related vein, the development of AI makes us question whether IP is fundamentally anthropocentric, in the sense of viewing human beings as the central or most 7 important entities in the universe. If so, IP law in the future may increasingly valorise the process of creation, rather than the end product. Will IP seek to protect what is uniquely and distinctly human? Is IP law inherently and essentially anthropocentric? Uma Suthersanen Interesting questions of power and politics also exist in relation to creative AI algorithms. In particular, if creative AI algorithms are awarded new or enhanced IP rights in the future, who stands to win and who stands to lose? Concerns have been raised that allowing the owners of AI algorithms to own the outputs of such algorithms may lead to mass acquisition of property rights and wealth of a small number of organisations and individuals. If the extensions of IP law in the twentieth century was, as some have claimed, a 'second enclosure' movement, where intangible commons of the mind were subject to property rights en masse, are we now on the precipice of a third enclosure movement in which the outputs of machines become privatised?

CHAPTER FIVE

The Intellectual Property Legal Framework Governing Artificial Intelligence Generated Works in Uganda

The Constitution of the Republic of Uganda, under Article 189(1) read together with the sixth schedule[105] of the constitution makes copyright, patents and all other forms of intellectual property the responsibility of the government. As a result, Uganda has the responsibility to establish a mechanism for protection of intellectual property. As a result, the government has enacted legislations governing intellectual property that govern copyright and patent law respectively. The Copyright and Neighbouring Rights Act 2006 and the Industrial Property Act 2014 are looked at because of their direct relevance to Artificial Intelligence.

Uganda is also part of the Intellectual property legal frameworks governing patents and Copyright on the international, and regional level. This chapter will cover the International, regional and the domestic legal frameworks governing AI-generated works beginning with Copyright law and later Patent law. The chapter will then look at whether AI-generated works fulfil copyright and patent law requirements such as originality and inventive step respectively. This is because the concept of originality is the heart of copyright law whereas under patent law, the concept of inventive step deals with non- obviousness of the invention which is the "ultimate condition of patentability" and the most important of the basic patent requirements.

[105] Sixth schedule (Functions and services for which government is responsible), under para 6.

INTERNATIONAL INTELLECTUAL PROPERTY FRAMEWORKS GOVERNING AI-GENERATED WORK COPYRIGHT LAW

Uganda is a member of the World Trade Organization (WTO).[106] As a member of the WTO, it is a signatory to the 1994 Agreement on Trade-Related Aspects of intellectual property (TRIPS Agreement).[107] The TRIPS Agreement applies to both copyright and patent law. The Agreement lays down minimum standards for the protection of intellectual property amongst WTO members.

The Agreement sets these standards by requiring that the substantive obligations of the main conventions of the WIPO, the Paris Convention and the Berne convention in their most recent versions be complied with.[108] Article 3 of the TRIPS mandates upon member states to 'accord to the nationals of other members treatment no less favourable than that it accords to its own nationals with regard to the protection of intellectual property'. It basically mandates parties to the Agreement to provide copyright to works by non-nationals on equal and similar terms as they do to nationals (national treatment). This therefore means that the copyright Act of Uganda applies to other non-nationals as it applies to Ugandans. However, it is important to consider whether the Act protects Al-generated works. Failure to do so may prompt other nationals to license AI-generated works in other countries that protect AI-generated works.

The TRIPS Agreement is silent as to whether the author of copyright has to be a legal or natural person. This position appears contradictory since the Agreement relies on criteria in Article 3 of the Berne Convention, which only recognizes

[106] WTO Agreement: Marrakesh Agreement Establishing the World Trade Organization, 15 April 1994, 1867 UNTS
154,33 ILM 1144.

[107] Agreement on Trade-Related Aspects of Intellectual Property Rights, IS April 1994, Marrakesh Agreement
Establishing the World Trade Organization, Annex ic (1994) 1869 UNTS 299, 33 TLM 1197.

[108] WTO, 'Overview: The TRIPS Agreement', *https:llwww.wto.org/english/tratop* e/trips e/inteI2 e.htm accessed April 22 2020.

natural persons.[109] Uganda is not party to the international instrument regulating Copyright law known as the Berne Convention for the Protection of Literary and Artistic Works (hereinafter, 'Berne Convention'). Even so, its criteria for eligibility of protection of copyright was incorporated in TRIPS, and to this extent, it is relevant to non-parties like Uganda.

Article 10(1) of the TRIPS provides that computer programs are protected as literary works. Furthermore, data compilations whether in machine-readable or other form, which by reason of selection or arrangement of their contents constitutes intellectual creations are protected as such, even though this protection does not extend to data itself.

Article 9(2) of the TRIPS expressly states that copyright protection shall extend to expressions and not to ideas, procedures, methods of operation or mathematical concepts as such. This means that AI algorithms cannot be copyrightable or patentable since they are mathematical methods.

Uganda is also party to the WIPO convention which is a multilateral treaty that establishes the World Intellectual Property Organization. WIPO is a global forum for intellectual property (IP) services, policy, information and cooperation which aims at developing a balanced and effective international IP system that enables innovation and creativity. On September 27 2019, WIPO held its first Conversation on IP and AI bringing together member states and other stakeholders to discuss the impact of Al on IP policy, with a view to collectively formulating the questions that policymakers need to ask. This has been followed by a public consultation process on artificial intelligence (AI) and intellectual property (IP) policy, inviting feedback on an issues paper designed to help define the most-pressing questions likely to face IP policy makers as AI increases in importance.[110]

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[109] Herman Tuhairwe and Maureen Kemigabo, '*To* what extent does Uganda's Copyright and Neighbouring Rights Act
2006 incorporate the TRIPS Agreement's standards?' 2019, Vol. 14, No.6, Journal of Intellectual Property Law & Practice, 456

[110] WFPO, 'impact of Artificial Intelligence on IP policy'https:llwww.wipo.intJabout-

PATENT LAW

Uganda is also a signatory to the Paris Convention and the Patent Co-operation Treaty (PCT).[111] The Patent Co-operation Treaty (PCT) makes it possible to seek patent protection for an invention simultaneously in each of a large number of countries by filing an "international" patent application. Such an application may be filed by anyone who is a national or resident of a PCT Contracting state. It may be generally filed with the national patent office of the Contracting State of which the applicant is a national or resident or, at the applicant's option, with the international Bureau of WIPO in Geneva.[112]

Article 4 of the Paris Convention grants the inventor the right to be mentioned as such in the patent. It makes no indication of whether AI systems can be given a right to be named as the inventor. However, Article 1.3 of TRIPS refers to a natural or legal person as an inventor stating that "in respect of the relevant intellectual property right, the nationals of other members shall be understood as those natural or legal persons that would meet criteria for eligibility for protection provided for in the Paris Convention (1967), the Berne Convention (1971) et al. As a Least Developed Country (LDC), Uganda has a transitional period, extending to 2021, in which to implement the general provisions of the TRIPS Agreement.[113] However, this transitional period has been further extended until 1st January 2033 in relation to pharmaceutical patents and clinical data.[114]

At the regional level, Uganda is a member of the Lusaka Agreement on the creation of the African Regional lntel1ectual Property Organization (ARIPO). As an ARIPO member, Uganda is a signatory to the Harare Protocol on Patents and Industrial Designs within the framework of the African Regional Industrial

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ip/enlartificial intelligence/call for comments accessed April 22,2020.

[111] Ibid

[112] WIPO, Patent Cooperation Treaty (PCT), httj?s:/Iwww.wipo.intitreaties/eniregistration/pctJ accessed at April 22, 2020.

[113] Article 66.1 of the WTO TRIPS Agreement.

[114] World Trade Organisation, 'Intellectual Property: Least Developed Countries', https:llwww,wto.org!english/tratop e/trips elldc e.htm accessed at October 11,2020

Property Organization. Uganda is also a member of the East African Community. Under the Harare Protocol, section 3 provides that an ARIPO Patent application shall identify the applicant, contain a sufficiently clear and complete description of the invention, a claim or claims and an abstract as well as the designate the contracting state. The provision does not expressly provide for who may be identified as the applicant of an ARIPO patent application.

Patent requirements under the Harare Protocol.

Section 3(10) of the Harare Protocol provides that patents shall be granted for any inventions, in all fields of technology, provided that they are new, involve an inventive step and are susceptible of industrial application. Section10 (b) provides that an invention shall be considered to be new if it is not anticipated by prior art. The protocol defines prior art as everything made available to the public anywhere in the world by means of written disclosure (including drawings and other illustrations), an oral disclosure or by use or an exhibition provided that such publication occurred before the time of filing of the application. However, it states that a disclosure of the invention at an official or officially recognized exhibition shall not be taken into consideration if it occurred not more than 6 months before the filing date. According to the protocol, an officially recognized exhibition is an exhibition recognized by the state. Section 10 (e) provides that an invention shall be considered as involving an inventive step if, having regard to prior art, it is not obvious to a person skilled in the art.

The Harare Protocol provides non-patentable inventions to include the following; the discoveries, scientific theories and mathematical methods, schemes, rules and methods for performing mental acts, playing games or doing business and programs for computers.

Under the Harare protocol, the ARIPO office may act as receiving office under Article 2(xv) of the Patent Cooperation Treaty in relation to an international application filed by an applicant who is a national or resident of a contracting state which is bound by the patent Cooperation Treaty. This provision implies that only humans can apply for patents in Al-generated works since AI has no legal status to be recognized as a citizen or a resident of Uganda. Rule 5 provides that where the applicant is the inventor, a statement shall be made to that effect in the application for a patent. And where he/she is not, the name and address of the inventor accompanied by a statement specifying the basis of the applicant's right to the patent. Given, that Al machines cannot contract, the applicant would lack the basis for being granted the right to the patent as was held in the DABUS case.[115] The Applicant filed statements of inventorship for patent applications of AI-generated works stating that the inventor is an AI machine called DABUS and that the applicant acquired the right to grant of the patents in question by virtue of ownership of the creative machine DABUS. The UK patent office held that there appears no law that allows for the transfer of ownership of the invention from the inventor to the owner as the inventor cannot itself hold property.

Uganda is also part of the East African Community. The East African Community is a creature of the Treaty establishing the East African Community which was signed in 1999. Under the EAC treaty, members are called upon to harmonize all their national laws appertaining to the East African Community. Under Article 43 of the Treaty, the member states committed themselves to promote and protect creativity and innovation for economic, technological, social and cultural development. Article 43(2) is more elaborate by setting out specific areas of cooperation to include; copyright and related rights and patents. Within this provision, EAC members have undertaken to introduce the protection of IPRs. It remains to be seen whether intellectual property law in EAC countries promotes creation and innovation in Al-generated works.

AI AND COPYRIGHT LAW

Copyright relates to new original artistic, literary, dramatic or musical works. This includes computer programme code, compilations of data and graphics. Copyright provides the exclusive legal right to produce, reproduce, publish or perform an original literary, artistic, dramatic or musical work.

[115] Re Stephen Thaler BL 01741/19

Copyright is an important IP asset for AI, as it protects the technology product (code and data) from unauthorised use and reproduction. Contributors to the technology should be identified and tracked. Ownership and confidentiality of the copyright should clearly be set out in a written agreement.

Companies may also benefit from placing digital locks on their products and services for security. Circumvention of digital locks is an offence in some jurisdictions and may provide relief against unauthorised parties. Companies should have policies for developers incorporating third-party copyright, even if inadvertently, as it may impact ownership of the technology and freedom to operate. Employees or a contracted developer, for example, may incorporate third-party source code without authorisation, which may impact ownership and could create inadvertent liability of infringement of other's IP rights.

AI systems involve large data sets which can be protected by copyright as compilations of data. These data sets and underlying algorithms are important IP assets for the company. Contractual terms with end users and third parties should clearly specify permitted use.

AI systems can also generate new works protectable by copyright, such as creating new artwork or music. However, most copyright statutes do not yet not clearly define who owns machine-generated works. It is currently a point of contention in respect of some such works whether the work is generated by a machine, and or the role played by the humans in creation of the work. To this end, agreements should attempt to clarify ownership when possible. Further, an AI system may act or operate autonomously in a manner that infringes third-party IP rights. If existing laws do not extend liability to a machine, then a related stakeholder (such as the owner, developer, operator or another supply chain participant) may be responsible.

Authorship:

Section 2 of the Copyright and Neighbouring Rights Act, 2006 defines the term "author" to mean the physical person who created or creates work protected under section 5 and includes a person or authority commissioning work or employing a person making work in the course of employment. Section 11 that provides for joint authorship states that where a work is created more than one person and no particular part of the work is identifiable to have been made by each person, such that such work is distinguishable, all the authors shall be co-owners of the economic rights and the moral rights relating to that work and the co-owners shall have equal rights in that work. Both these provisions are human centered and do not recognize non-human authorship by AI machines. The resulting effect would be that autonomously generated AI works would fail to be eligible for copyright protection simply because they are machines. Such work would fall into public domain. This would de-incentivize creation and innovation in AI-generated works because of limited innovation and less investment in AI research.

Section 4 states that the author is entitled to copyright protection of his/her work where it is original and reduced in material form irrespective of the quality of the work where it is original and reduced in material form irrespective of the quality of the work. Section 4(3) states that work is original if it is the product of independent efforts of the author.

Section 5 outlines work eligible for copyright to include literary, scientific and artistic work such as dramatic and musical works, audio-visual works and sound recording, computer programs, works of drawing, derivative works among to mention a few. AI software code can be categorized as a computer program and would therefore qualify for copyright protection as long as it satisfies the relevant requirements including originality (copyright is the main tool for protecting software). AI-generated works may qualify as derivative works, lastly, section 6 provides that ideas and concepts are not protected by copyright.

Authorship: Distinguishing between AI aided creations and AI-generated creations

Copyright protects the software programmes which make up the building blocks of the AI system.[116] The question is: Who is the author in copyrightable work generated by AI? Traditionally, the authorship or ownership of copyrightable works which are computer generated was not in doubt. The popular

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[116] WIPO, 'Copyright' bttps:/Iwipo.intlcopvrightlenJ accessed 2nd March, 2020.

belief is that since a computer is a man-made invention, it is deemed a tool in the hand of the human creator, consequently authorship of the resultant work would belong to the human creator. The current impact of AI is starting to disrupt this seemingly rigid traditional presumption[117] with AI now able to generate creations. To answer this question, it is important to distinguish between Al-aided creations and AI-generated creations. When generating AI-aided creations, AI is largely employed in the creation of copyrightable work as a tool to enhance human creativity. In 1990s, David Bowie generated lyrics for his Berlin trilogy of albums using a 'verbasizer' which randomized sentences to create unexpected word combinations.[118] Visual artist Anna Ridler uses artificial intelligence as a tool to create art. In both cases, despite the involvement of a machine, the final output landed squarely within the boundaries of what the human artist intended to create[119].

In Robin Ray v Classic FM pic,[120] it was held that someone acting as a mere scribe, producing the copyright expression accurately without making any creative contribution whatsoever, can never be an author or co-author of a work. Lightman. J was of the view that there must be that essential creative input, 'a direct responsibility for what actually happens on the paper,' to satisfy the test of authorship. There in cases where AI machines only take instructions from the programmer without having any creative input in the resulting work, authorship vests in the human programmer and AI are deemed as just a tool. On the other hand, it is possible that an Al-program develops the art on its own. The program creates the work with little or no aid of a user. Hence, these creations are made in absence of any or little - human intervention or creative input at the time of the creation of

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[117] Anjana Viswanath, 'Intellectual Property and Artificial Intelligence, 8th October 2019, https:/ fwww.mondag.com/indiafl intellectual- Property/8521861Intellectua 1-Property- And- Artificial-Intelligence accessed 2nd March 2020.

[118] Emma Pike, Artificial Intelligence & Intellectual Property: should machine own rights, August 2019, https:/lwww.hkstrategies.com/arti artificial- intelligence- intellectual- property-should-machines-own-rights accessed I1th march 2020

[119] *Ibid*

[120] [1998] EWHC Patents 333

the work. Works like these are referred to as AI- generated creations. In these cases, the machine cannot own rights because it is not a human as will later be illustrated in the legal regime governing authorship. And the human behind the machine will fail to meet key criteria to claim IF 'originality' for copyright because they did not create the work. As a result, AI generated creations forge a loophole in IP law.

Whether AI-generated creations can be protected by Copyright law

Copyright is an intellectual property right which exists to protect literary, dramatic, musical and artistic works[121]. Copyright is particularly important for creative industries because it protects the creative or artistic expression of an idea, not the idea itself. It is a legal right granted to the creator of an original work, allowing him or her exclusive rights for its use and distribution, The rationale and justification behind this is the notion that the author is an originator merged with Locke's economic theory of possessive individualism[122] which states that an individual deserves to reap the rewards of his/her labour.

Generally, for a grant of a copyright, fulfilment of two essential features is required. First, the work should be in tangible form, and secondly, it should be original[123]. On the requirement that for a work to be protected, it must be reduced in tangible form, the decision in Gould Estate v Stoddart Publishing Company[124] is authoritative. In that case, the Ontario Supreme court in Canada considered whether the plaintiff enjoyed copyright in oral conversations which the publishing company reduced into writing and published after the death of Gould. The court held that the conversation was not a literary work because it was not expressed in a material form. Similarly, in Tate v Fulbrook,[125] court held that a

[121] Davies C (n.23).
[122] T. Swapnil and Chadni Ghatak •. Artificial Intelligence and Intellectual Property' (2018) Christ University Law
Journal 86.
[123] Ibid
[124] Gould Estate v Stoddart Publishing Company (1996) 39 OR 555.
[125] Tale v Fulbrook (1908) I KB 821.

usual skit for a musical hall sketch involving the use of fireworks was not a subject of copyright because it had not been reduced in writing.

The concept of originality: Sweat of the brow doctrine vis-a-vis Modicum of creativity

In the case of *Ladbroke Football Ltd v William Hill Football Ltd,*[126] court stated that originality which is required relates to expression of thought. That the Act does not require that the expression must be in an original or novel form, but that work must not be copied from another author. That originality is a matter of degree depending on the amount of skill, judgment or labour that has been involved in the making the compilation. This standard of originality is what is referred to as the "sweat of the brow" doctrine. It provides copyright protection on the basis of labour, skill and investment of capital put in by the creator instead of originality. Most common law systems traditionally follow the degree of skill and labour involved while continental countries put more weight on the levels of creativity.[127] Uganda's concept of originality in copyright law is based on the "sweat of the brow" standard which does not require any form of substantial creativity. However, the concept of «originality" has undergone a paradigm shift from the "sweat of the brow" doctrine to the "modicum of creativity" standard put forth in Feist Publication Inc. v Rural Telephone service[128] by the United States Supreme court. The Supreme Court totally negated this doctrine and held that in order to be original, a work must not only have been the product of independent creation, but it must also exhibit a 'modicum of creativity'. The Supreme Court prompted 'creative originality' and laid down the new test to protect the creation on the basis of minimal creativity. This doctrine stipulates that originality subsists in a work where sufficient amount of intellectual creativity and judgment has gone into the creation of that work. The standard of creativity need not be high but a minimum level of creativity should be there for copyright protection.

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[126] Ladbroke F o o t b a l l l t d v William H i l l Football l t d [1964] 1 All ER 465.
[127] Rosa Maria, Kan He & Teemu, Al-Generated Content: Authorship and inventorship in the Age of Artificial Intelligence' Helsinki Institute for Information Technology (2019) https:llwww.cs.helsinki.ftlulttonteri/pub/aicontent20 18.pdf
[128] 499 U.S. 340.

When it comes to whether AI machines can exhibit the originality required for copyright protection, the case of Burrow Gilles Lithographic Co v Sarony[129] is insightful. Although the Burrow case was decided before Feist, it addressed the dichotomy between creative and mechanical labour. The case revolved around whether copyright protection can be granted to a photograph. The court discussed the possibility of granting copyright protection to a product which is the output of a machine. The court, by holding that purely mechanical labour is per se not creative, narrowed the scope of their protection. Therefore, a strict approach requiring a modicum of creativity to be applied to Al systems would make granting copyright for works created by Al-generated works difficult.

On the other hand, section 5 of the Copyright and Neighbouring Rights Act of Uganda recognizes derivatives as work eligible for copyright. Since AI is dependent on existing information and exposure of the programming, work so created may qualify for copyright as a derivative work and therefore protectable by copyright so long as they are selected and arranged to form an original work. AI is already capable of doing that.

Recently, a court in Shenzhen, Guangdong province in China, ruled recently that a work generated by artificial intelligence qualified for copyright protection.[130] On August 20, 2018, the plaintiff first published on the Tencent Securities website a financial report titled "Lunch Review: Shanghai index rose slightly by 0.11% to 2691.93 points led by telecommunications operations, oil extractions and other sectors". Tencent personnel used the Dream writer AI to draft the article and when the plaintiff published the article on its website, it stated that the Tencent Dream writer Al automatically wrote the article. The defendant, Shanghai Yingmou Technology Co., Ltd., disseminated the same article to the public through a website operated by the defendant on the same day the plaintiff published the

[129] 111U.S.53

[130] Shenzhen Nanshan District People's court: *Shenzhen Tencent Computer Systems Co. Ltd.* v *Shanghai Yingmou Technology Co., Ltd* cited in 'Shenzhen Court Rules Al-Generated Articles are Entitled to Copyright Protection' National Law Review 3 January 2020 https: llwww.natlawreview.com/article/shenzhen-court-rules-ai-generated-articles-are-entitled-to-copyright-protection accessed 3 September 2020

article. The court stated, the Tencent team members used the Dream writer software to generate the article in issue and met the legal requirements to be a written work and accordingly was a legal person's work created by the plaintiff. Accordingly, the court ordered the defendant to compensate the plaintiff for the economic losses and fees associated with enforcement.

AI And Patent Law

Inventorship:

Section 2 of the Industrial Property Act defines an «inventor" to mean the person who actually devises the invention as defined in section 8; and includes the legal representative of the inventor. Section 17 of the Act provides that the right to a patent belongs to the inventor. Section 17(2) continues to state that where two or more persons have jointly made an invention the right to the patent belongs to them jointly. Section 20 states that the inventor shall be named as inventor in the patent application unless she indicates that he/she wishes not to be named. These provisions reflect the notion that inventorship under Uganda's patent law is limited to only natural persons like in most countries of the world.

Section 8(3) states that discoveries, scientific theories and mathematical methods shall be excluded from patent protection. It also excludes schemes, rules or methods of doing business, performing purely mental acts or playing games.

Section 9 provides that an invention is patentable if it is new, involves an inventive step, and is industrially applicable.

Whether AI-generated creations can be protected by Patent law

A patent can be understood as the exclusive right granted for an invention which is a product or a process that provides, in general, a new way of doing something, or offers a new technical solution to a problem.[131] Due to the strength of this form of property right, high standards are required - the invention must be new and it must

[131] WIPO, 'Patents: What is a patent?' https:llwww.wipo.intlpatents/en accessed March 3, 2020.

involve an inventive step, that is, it must be more than merely an obvious application of technology. Furthermore, the invention must be capable of industrial application and must not fall within certain stated exclusions. Patent law grants a monopoly for a limited period of time in respect of an invention in return for disclosure of the details concerning the invention. These details are available for public inspection and are sufficiently comprehensive so that a person skilled in the particular art would be able to make practical use of the invention; in other words, he would be able to work the invention.[132]

The interaction between Patent laws and AI is increasing in today's technological world. AI has been used extensively in order to simplify the execution of basic functions and primarily reduce human effort. AI enabled systems are equipped to perform tasks based on their own key learnings, creating a possibility of them inventing something.[133] This poses a new challenge from a legal standpoint, i.e. from the perspective of patent law.

Uganda is also a signatory to the Paris Convention and the Patent Co-operation Treaty (PCT).[134] The Patent Co-operation Treaty (PCT) makes it possible to seek patent protection for an invention simultaneously in each of a large number of countries by filing an "international" patent application. Such an application may be filed by anyone who is a national or resident of a PCT Contracting state. It may be generally filed with the national patent office of the Contracting State of which the applicant is a national or resident or, at the applicant's option, with the international Bureau of WIPO in Geneva.[135]

AI is already capable of generating inventions that can be granted patent protection. A case in point is the creative Machine, developed by Al pioneer Stephen Thaler in 1994 that was already capable of generating new ideas through artificial neural networks. It is also known for having generated an invention that was ultimately

[132] David B, Intellectual Property Eighth Edition, 377.
[133] Swapnil T and Chadni Ghatak (n.92) 90.
[134] Ibid
[135] WIPO, Patent Cooperation Treaty (PCT), httj?S:/I www.wipo.intitreaties/eniregistration/pctjaccessed at April 22, 2020.

issued a US patent No. 5,852,815 which became the first known patent to be issued to an Al-generated invention. But Thaler listed himself as the sole inventor and did not disclose the creativity Machine's involvement to the United States Patent Office.[136] However, it remains to be seen whether Al-generated creations can fulfil the requirements necessary to be granted patent protection.

Patent law does not protect Artificial intelligence inventions themselves. This is owing to the fact that they fall under non patentable subject matter because they consist of algorithms. According to section 8 of the Industrial Property Act, scientific theories and mathematical methods are excluded from patent protection. This has been expounded upon by the supreme court of the United States (SCOTUS) which states that "they are basic tools of scientific and technological work," and that granting monopolies on these tools through patent rights impede innovation.

Furthermore, the Supreme Court, in Alice Corporation Pty. Ltd. V CLS Bank International[137] recently made it more challenging for applicants to obtain patents on "computer-implemented inventions". The seminal Alice decision has been interpreted to exclude patent claims directed to subject matter that could be performed through an "ordinary mental process", "in the human mind" or by "a human using a pen and paper", with limited exception for claims that specifically provide for ways to achieve technological improvements over the tasks previously performed by people (e.g. containing an inventive concept). This aspect of Alice's legal framework created tension with AI patents because the goal of AI is often to replicate human activity. Similarly, in Blue Spike, LLC v Google Inc.,[138] applying the Alice test, the court held that patent claims covered a general purpose computer implementation of "an abstract idea long undertaken within the human mind" because they sought to model "the highly effective ability of humans to identify and recognize a signal" on a computer. Court found that the claims covered "a wide

[136] World Economic F o r u m (n.20) 6.
[137] 573 U.S. 208 (2014).
[138] No. 16-1054 (Fed. Cir. 2016).

range of comparisons that humans have undertaken since time immemorial" and thus lacking any "inventive concept".

Another issue when it comes to patentability of AI-generated works is what amounts to inventive step. One of the criteria of patentability is that a creation must exhibit sufficient "inventive step" or must be non-obvious. The inclusion of such a requirement is based on the premise that patent protection should not be given to anything that a person with ordinary skill could deduce as an obvious consequence of what is already known to the public. An invention that is simply obvious in relation to the existing art would contribute very little, if anything at all, to society. As one scholar stated, the inventive step or non-obviousness is in some respects the heart and soul of patentability, separating the true innovative wheat from the chaff of unpatentable minor improvements. A condition of patentability is that the invention involves an inventive step or be non-obvious. The standard applied for assessing non-obviousness is whether the invention would be obvious to a person skilled in the relevant art to which the invention belongs. In regards to AI- generated inventions, the question is: Should the standard of a person skilled in the art be maintained where the invention is autonomously generated by an AI application or should consideration be given to replacing the person by an algorithm trained with data from a designated field of art?[139]

Article 4 of the Paris Convention grants the inventor the right to be mentioned as such in the patent. It makes no indication of whether AI systems can be given a right to be named as the inventor. However, Article 1.3 of TRIPS refers to a natural or legal person as an inventor stating that "in respect of the relevant intellectual property right, the nationals of other members shall be understood as those natural or legal persons that would meet criteria for eligibility for protection provided for in the Paris Convention (1967), the Berne Convention (1971) et al. As a Least Developed Country (LDC), Uganda has a transitional period, extending to 2021, in which to implement the general provisions of the TRIPS

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[139] Un published thesis by ....

Agreement.[140] However, this transitional period has been further extended until 1st January 2033 in relation to pharmaceutical patents and clinical data.[141]

Patents provide incentives to individuals by offering them recognition for their creativity and material reward for their inventions. These incentives encourage innovations which ensure that the quality of human life is continually enhanced. All the patent owners have an obligation in return for patent protection to publicly disclose information on their innovations in order to enrich the body of technical knowledge that exists as such an ever-increasing knowledge of public promotes further creativity and innovation. In this way the patents not only provide protection for the owner but also valuable information and inspiration for the future generation

Brand

A trade mark is unique and identifies the source of the goods and services with which it is associated. It may consist of a combination of letters, words, sounds or designs that distinguishes one company's goods or services from those of others in the marketplace. A strong brand helps AI companies differentiate their products and services from competitors and establish a strong reputation in the market. AI technology and algorithmic accountability can help a company develop goodwill for its brand. AI companies are often stewards of important data assets, and documentation should consider these as valuable assets and document and register IP when possible. A reputable brand may be of paramount importance to customers. An AI tool can be a 'black box' device embedded within a finished product offered by a third party. This can make it difficult for the end customer to recognise the brand of the company supplying the 'black box'. A co-branding agreement can provide for use of the mark associated with the 'black box' on the finished product offered by the third party. This can help the 'black box' provider become recognisable by the end consumer.

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[140]Article 66.1 of the WTOTRIPS Agreement.

[141]World Trade Organisation, 'Intellectual Property: Least Developed Countries', https: llwww,w to .org! English /tratop e/trips ell dc e.htm accessed at October 11,2020

How Are Patents Granted And Who Grants It?

The first step in securing a patent is the filing of a patent application. The patent application generally contains the title of the invention as well as indication of its technical field. You must include the background and in a clear language and enough detail that an individual with an average understanding of the field could use and reproduce the invention. Such descriptions are usually accompanied by usual materials like drawings, plans for better describing the invention.

At present, no world patent or international patent exist. In general, an application for a patent must be filled and the patent shall be granted and enforced in each country in which you seek patent protection in accordance with the laws of that country.

Types Of Patent Protection

Patent protection can be under 3 types of categories

Utility patents

Design patents

Plant patents

Utility Patents

These apply to new and useful process, machines, manufacturing process, composition of given matter or any new and useful improvements of one of these. Generally, if a particular invention does something, then one can apply for utility patents. Utility patents are traditionally further divided in 3 basic types; mechanical, electrical, chemical.

Pharmaceutical patents are in most cases treaties as a special case of chemical patents.

Design Patent

These apply new, original and ornamental designs or an article or manufacture. The major difference between design and utility patents can be seen in today's computers and phones. Under this, the plastic shell that covers all the working parts is covered by a design patent while all the many working designs it has are covered by utility patents.

Plant Patents

These are granted by any person who has invented or discovered and a sexually reproduced any distinct and new variety of plant including cultivated hybrid and newly found seedlings (protection of Plant varieties see Article 27 (3)); by patent, by an effective sui generis system, any combination thereof.

Patents are provided for under **Article 27 in the TRIPS** agreement. This article requires that for a patent to be granted it should be for an invention that is either a product or process in all fields of technology provided that the process is new, involves an inventive step and is capable of industrial application.

The article provides that member states may exclude invention from patentability on a number of grounds including where it important to protect a public order or morality & protection of human, animal and plant life and invention that may be pre-judicial to the environment.

The article further excludes from patentability, the diagnostic & surgical methods of treatment of animals & humans and also recognizes that plant varieties could be protected under patents & effective sui-generis system on a combination of the law.

The Concept Of Novelty

The novelty test determines if the subject matter the invention has been previously known by others. It is important to note that novelty is not something that can be proved or established but it is rather something that can be proved through determining its absence. This means that the key issues under novelty always revolve around establishing its absence. Key to the novelty test is the concept of prior art. This refers to the existing body of knowledge either written or oral that governs the planed subject matter of the invention. In this light, an invention is deemed novel (new) if it's not predated by prior art i.e., if prior to the filling of the patent application, an invention does not already exist as part of the body of knowledge know in the planed subject matter.

Article 27 of the TRIPS agreement recognizes novelty as one of the key aspects for patentability of an invention. It is important however to note that the TRIPS agreement does not make an effort to unpack what the concept of novelty should mean for the member states as such, member states have the liberty to determine what constitutes novelty in their national legislation of patents. In Uganda the patent Act addresses the aspect of novelty under section 9.

This section 9 emphasizes that an invention is new if it is not anticipated by prior art. The section further defines prior art everything made available for the public anywhere in the world by means of written disclosure including drawings and other illustrations or by oral disclosure including through use and any other non-written means. A couple of exceptions need to be considered as provided under **section 9 (2).** The Uganda law also mentions that disclosure to the place of the invention should not be taken into consideration if this occurred within 12 months preceding the date on which the application was filed and this should be by reason of consequence of either acts committed by the or his or her predecessor or by an abuse committed in relation to the applicant or his or predecessor in the title.

As such it is important to note that prior art is lost if disclosure is proved and this may be under three main instances;

Printed publication-under this description of an invention may be published in a writing or in a publication but this must be in a tangible format and they are in most cases be a physical carrier of the information which makes the subject available to the public.

Oral disclosure-the description of the invention in words spoken in place (not necessarily recorded) will also amount to prior art of that invention in question. This may include lectures and radio broadcasts

Disclosure by use-this includes the use of the invention in public or putting the public in a position that enables them to know about the invention.

The common type of usual disclosure includes putting the invention on sale or display, public demonstrations, unrecorded television broadcast and an actual public use. For document to destroy the novelty of an invention it must clearly and fully describe the subject matter described in the document.

The invention is then found not to be novel if the document involves all the characters of the claim in question and in that case the document is said to have anticipated the subject matter of the pending application and the existence of prior art is claimed.

It should also be noted that when considering novelty, it possible to combine separate items with prior art together. In the case of **Windsurfing international Inc v Tabur marine [1985] RPC 59** it was highlighted that a product which preceded the patent would infringe or affect the right of the patent if it surfaced at a later date. In this particular case, prior art was deemed to have happened under the act of the use with the publication. The case points out that its only public information that and taken into account but no matter it is substituted and in what language it is written as long as it discloses the invention it will destroy the patentability of the invention in question.

The parameter for determining novelty would seem to be fairly objective as long as the invention has been made available to the public. This was also interpreted in **GENETECH-INC'S PATENT (1989) RPC 147** where it was noted to form part of the state of the art, the information given by the user must have been available by at least one member of the public who was free in law to make use of it. The implication of this judicial interpretation is that if the information to a person or group of persons under circumstances which make it to disclose to any other person or to make use of the invention cannot be said to having not been available to the public as to form part of the state of the art. It has also been judicially interpreted that to form part of the state of the art the disclosure of the invention must be an enabling disclosure and must have provided sufficient information to enable the person skilled in that art to make use of it. The courts have also tended to be very willing to declare that an invention has been made to the public where there is a possibility that the particular person has further disclosed the information to more than one person, for instance it has been held that if the invention was disclosed by a book which has not been sold but only displayed only in a book shop.

It was stated that sufficient disclosure had been made to make the invention part of the state of the art. Similarly, where a book is written in French and it is in a British museum in a room not accessible to the public but its title on summary is included on the catalogue, it has been held that it had been made available to the public.

In the case of **MERRELL pharmaceuticals V NORGHTON** it was noted and held that prior use of a product was to be considered in the same way as prior use published document but, in both cases, prior use will only invalidate where the information made available will enable the person skilled in the art to work the information to make the invention.

Inventive Step Or Non-Obviousness Of An Invention

One of the most complex aspects of patent law is the determination of inventive step or non-obviousness of an invention. Inventive step is judged through a line of thought that a man is skilled in the art but lacks in the inventive genius. A skilled person is one having all the standard knowledge available in the field and having the standard capabilities of routine work and experimentation allowing him to straight forward progress from what is already known. Such a person nearly has a sense of what is possible but lack the imagination/inventiveness and has no benefit of foresight beyond the available knowledge.

The question to be asked is whether this normal skilled person would have used his mind to make a breakthrough in the alleged invention. This is a critical step in the requirement. For one to be able to move beyond a new innovation to something that is not obvious to a person skilled in the art. The trips agreement under **Article 27 (1)** provides that for an invention the subject of patent should involve an inventive step.

According to **section 10 of the Patents Act**, an invention is said to have an inventive step if having regard to prior art as defined in **section 9**, it would not have been obvious to a person skilled in the art, on the date of filling of the application and if priority is validly claimed, the time considered is the priority date.

It is important to keep in mind the essence of an invention, which includes the identification of a problem, creation of a solution to that problem and guarantee that the result will be positive in applying the solution created.

If the problem is known/considered obvious, then the inventive step of the solution is examined. If there is no originality found in the solution, then the assessment passes on to the result to determine if the result is obvious or whether it is surprising either by its nature or its existence. Thus, there lacks an inventive step if a person with the ordinary skill in the given art is unable to pause a problem, solve the problem and foresee the results.

In Hotchkiss v Greenwood 52 US

Court noted that unless more ingenuity and skill in applying the old method of fastening the knob were required in the application of the same to the clay knob than were possessed by an ordinary mechanic acquainted with the business, there was an absence of the degree of skill and ingenuity that constitute essential elements of the invention. In other words, the improvement in the work of a skilled mechanic and not an inventor is required to pass the test of non-obviousness.

This case emphasized the fact that patents would only be granted to something that is a novel invention and not just a minor improvement in the existing knowledge.

In Graham v John Deere company

Court found that patents were only intended for those inventions which were new, useful, furthered human knowledge rather than for small and details and obvious improvements. Courts found the following as the factors for determining non-obviousness;

- Scope and content of prior Art

- Differences between the claimed invention and prior art
- Level of ordinary skill in the prior art
- Secondary considerations e.g., commercial success, unresolved needs, failure of others.

Court found that Graham's invention served the same purpose as the 1st one and technically the improvement was found to be obvious by anyone who read Graham's patent.

INDUSTRIAL APPLICATION

Industrial application refers to the usefulness of the invention in question. It is not every invention which is new and involves an inventive step could be patentable. This is because patents are designed to promote industrial development and they provide incentives for creativity for people involved in the research and industrial development endeavours. Just like novelty and inventive step, industrial application is required by Article 27(1) of TRIPS Agreement. This article defines Industrial application to be synonymous with the term usefulness. As such, countries are at liberty to determine what is useful before being patented at the national level.

Section 11 of the Patents Act, Uganda considers Industrial application to include inventions that are considered industrially applicable by their nature and can be technologically made, used in any industry.

In Lowell v Lewis

Court found for Lewis and held that to warrant a patent, the invention must be useful. Court defines usefulness as something that is capable of some beneficial use, in contradiction to what is frivolous or worthless. According to court, usefulness does not mean better, it just means different. It pointed out that a new invention to poison people or promote immorality, facilitate private assassinations may not be a patentable invention. If the invention steers wider of these objections, whether it be more or less useful, is a circumstance very immaterial to the interests of the patentee, but of no importance to the public. Basically, even if the patent was not as good as the other pumps on the market, it was still patentable. Court noted that it is extremely hard to judge what is better, as an invention might be worse than most things, but better for one specific thing.

The interaction between Patent laws and AI is increasing in today's technological world. AI has been used extensively in order to simplify the execution of basic functions and primarily reduce human effort. AI enabled systems are equipped to perform tasks based on their own key learnings, creating a possibility of them inventing something.[142] This poses a new challenge from a legal standpoint, i.e., from the perspective of patent law.

AI is already capable of generating inventions that can be granted patent protection. A case in point is the creative Machine, developed by Al pioneer Stephen Thaler in 1994 that was already capable of generating new ideas through artificial neural networks. It is also known for having generated an invention that was ultimately issued a US patent No. 5,852,815 which became the first known patent to be issued to an Al-generated invention. But Thaler listed himself as the sole inventor and did not disclose the creativity Machine's involvement to the United States Patent Office.[143] However, it remains to be seen whether Al-generated creations can fulfill the requirements necessary to be granted patent protection.

Patent law does not protect Artificial intelligence inventions themselves. This is owing to the fact that they fall under non-patentable subject matter because they consist of algorithms. According to section 8 of the Industrial Property Act, scientific theories and mathematical methods are excluded from patent protection. This has been expounded upon by the supreme court of the United States (SCOTUS) which states that "they are basic tools of scientific and technological work," and that granting monopolies on these tools through patent rights impede innovation.

Furthermore, the Supreme Court, in Alice Corporation Pty. Ltd. V CLS Bank International[144] recently made it more challenging for applicants to obtain patents

[142]Swapnil tandchadni Ghatak (n.92) 90.
[143]World Economic Forum (n.20)6.
[144]573U.S.208(2014).

on "computer-implemented inventions". The seminal Alice decision has been interpreted to exclude patent claims directed to subject matter that could be performed through an "ordinary mental process", "in the human mind" or by "a human using a pen and paper", with limited exception for claims that specifically provide for ways to achieve technological improvements over the tasks previously performed by people (e.g., containing an inventive concept). This aspect of Alice's legal framework created tension with AI patents because the goal of AI is often to replicate human activity. Similarly, in Blue Spike, LLC v Google Inc.,[145] applying the Alice test, the court held that patent claims covered a general-purpose computer implementation of "an abstract idea long undertaken within the human mind" because they sought to model "the highly effective ability of humans to identify and recognize a signal" on a computer. Court found that the claims covered "a wide range of comparisons that humans have undertaken since time immemorial" and thus lacking any "inventive concept".

Another issue when it comes to patentability of AI-generated works is what amounts to inventive step. One of the criteria of patentability is that a creation must exhibit sufficient "inventive step" or must be non-obvious. The inclusion of such a requirement is based on the premise that patent protection should not be given to anything that a person with ordinary skill could deduce as an obvious consequence of what is already known to the public. An invention that is simply obvious in relation to the existing art would contribute very little, if anything at all, to society. As one scholar stated, the inventive step or non-obviousness is in some respects the heart and soul of patentability, separating the true innovative wheat from the chaff of unpatentable minor improvements. A condition of patentability is that the invention involves an inventive step or be non-obvious. The standard applied for assessing non-obviousness is whether the invention would be obvious to a person skilled in the relevant art to which the invention belongs. In regards to AI- generated inventions, the question is: Should the standard of a person skilled in the art be maintained where the invention is autonomously generated by

[145]No. 16-1054(Fed.Cir.2016).

an AI application or should consideration be given to replacing the person by an algorithm trained with data from a designated field of art?

COMPERATIVE ANALYSIS OF THE USE OF AI

The United States of America

The US Copyright Act does not explicitly require human authorship. The Act protects 'original works of authorship' However, the US Court of Appeal in the notorious monkey **selfie case** affirms the position that only humans are entitled to copyright protection. In that case, a UK Wildlife photographer, David Slater had in July 2011, visited a wildlife park in Indonesia to take unique pictures of some rare macaque monkeys. At some point, he intentionally left his camera on a tri pod for monkeys to explore as they seemed curious. One of the monkeys named Naruto, took the camera and snapped "selfies" of itself. David Slater then went on to print and publish several copies of the pictures. An animal rights group, Peoples for the Ethical Treatment of Animals (PET A) sued Slater in 2015 on behalf of Naruto for copyright infringement.[146] The Ninth Circuit Court of Appeals upholding the judgement of the lower court dismissed the appeal by PETA and held that copyright protection cannot be granted to animals, being a non-human entity. This case clearly reinforces the general rule that non-human entities such as Al and other machines, are not entitled to copyright protection.

The United States Copyright Office updated its interpretation of "authorship" in 2016. This interpretation is rooted in section 313.2 of the Compendium of the Copyright office [Compendium] which states: "the office will not register works produced by a machine or a mere mechanical process that operates randomly or automatically without any creative input or intervention from a human author.[147] The consequence is that these creations fall into public domain.

United Kingdom

[146] *Naruto v Slater No*. l5-15469 (9th Cir. 2018).

[147] U.S. Copyright Office, Compendium of U.S. Copyright Office Practices S 10 I (3d ed. 2017), section 3.13.2)

UK is one of the few countries in the world that has an explicit provision protecting Computer generated works. In the Copyright, Designs and Patents Act 1988 (CDP A), a definition is given of a computer-generated work (CGW). A computer-generated work is a work that "is generated by computer in circumstances such that there is no human author of the work.[148] The CDPA incorporated such an exception to human authorship because it recognized that computers can generated works. However, it is important to differentiate between computer generated works and AI generated work. AI generated creations are made by an AI-program whereas computer generated works are created by the computer.

In the UK legal system, Section 9(3) of the Copyright Designs and Patents Act 1988 provides that "in the case of a literary, dramatic, musical or artistic work which is computer-generated, the author shall be taken to be the person by whom the arrangements necessary for creation of the work are undertaken". The important aspect of this provision is that it requires a human actor who makes the necessary arrangements in coming up with computer generated works. In the Nova productions case[149], the court of appeal had to decide on the authorship of a computer game. The court declared that the user's input "is not artistic in nature and he has contributed no skill or labour of an artistic kind". This case suggests that a way to identify who made the necessary arrangements is to look at the person who used skill, labour and judgment in that arrangement. The court ruled in favour of the programmer. The above stated provision is therefore an emanation of Ada Lovelace's understanding that a machine "can do (only) whatever we know how to order it perform".

In conclusion, the UK Copyright Designs and Patents Act 1988 is one of the pieces of legislation that recognize that non-human entities can generate copyright works with little or no human intervention as opposed to the position in US & Uganda which only recognize copyright works made by human authors. It therefore appears to be the more sensible approach of granting copyright protection to AI generated works. However, it can be stated that CDPA does not solve the dilemma

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[148] A. Michel, ' Al-Generated creations: Challenging the traditional concept of Copyright'. 48.
[149] *Ibid 52*

of ascertaining true authorship in AI autonomously generated works since it is based on the incorrect supposition that the computer is no more than a tool for the programmer or a person responsible for making arrangements necessary for the creation of the work to be undertaken. The CDP A does not envisage generation of autonomously generated Al works without the person who makes the necessary invention. In regards to Uganda's copyright law, it can be asserted that the law is not ready for the era of Artificial Intelligence since it does not provide protection for work generated by AI without any human interference.

In the US, the patent system only recognizes individuals as inventors[150] not companies or machines. Inventorship is determined by conception, or formation in the mind of the inventor of a definite and permanent idea of the complete and operative invention. This provision implicitly asserts that it is only the human mind capable of conceiving an invention. The use of AI, particularly deep machine learning or self-evolving and coding AI, raises questions as to who conceived of the invention and should thus be named as an inventor. [151] This presents two options: (1) list AI as the Inventor; or (2) list no inventors on the face of the patent.

In the UK, section 7(3) of the 1977 Patent Act defines what constitutes an inventor. It states that an inventor means the actual deviser of the invention. Section 13(2) requires the applicant (in cases where the applicant is not the inventor) to identify the "person or persons whom he believes to be the inventor or inventors". In the application for a patent by Stephen Thalerl[152] where he sought to register an Artificial Intelligence machine called "DABUS" as the inventor, one of the questions considered was whether a non-human inventor can be regarded as an inventor under the Act. The UK patent office held that:

" ... there is a clear expectation that the inventor and person for purpose of section 7 and 13 respectively are one and the same, namely a natural person - a human and

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[150] 35 U.S.C S 100(t).

[151] Suzan Y. Tull and Paula E. Miller, Patenting Artificial Intelligence: Issues of obviousness, Inventorship and Patent Eligibility', (2018) 5(1) *Journal of Robotics, Artificial intelligence &Law 318.*

[152] BL *01741/19.*

not an AI machine. There has never been any indication from the courts that this is an incorrect interpretation and it is settled law that an inventor cannot be a corporate body. Even though the invention itself is said to have been created by DABUS, the applicant acknowledges that DABUS is an AI machine and not a human, so cannot be taken to be a "person" as required by the Act ... It is thus not for the Office to take an interpretation of the law that was not intended upon implementation and where there have been no indications from the courts or legislature that a "person" should be construed as anything other than a natural person. Since DABUS is a machine and not a natural person, I find that it cannot be regarded as an inventor for purposes of section 7 and 13 of the Act."

In the DABUS case, the patent office observed that the fundamental function of the patent system is to encourage innovation by granting time-limited monopolies in exchange for public disclosure. The office also observed that patent system did not cater for inventions created by machines and that it was never anticipated that it would. The office, on the other hand, recognized that times had changed and technology had advanced and called for the issue to be debated more widely and changes to the law be considered in the context of the debate rather than shoe homing Al inventorship into existing legislation. In the case of Uganda, it is apparent that patent law does not provide for protection of works autonomously generated by AI as it only recognizes human inventorship. Therefore, Uganda's patent law is not ready for the era of Artificial intelligence. Any changes would need to be debated across the world-wide divide so that patent laws can be harmonized. WIPO has led consultations in member countries to address how intellectual property law like patents can be updated to provide for Artificial intelligence generated creations. However, any recommendations should aim at furthering IP objectives to incentivize creation and innovation.

CHAPTER SIX

Best Practices from other Jurisdictions Regarding Authorship and Inventorship In Ai-Generated Creations

The UK approach offers a more pragmatic solution to the question of authorship and inventorship in Al-generated creations. Section 9(3) of the CDPA provides that "in the case of a literary, dramatic, musical or artistic work which is computer-generated, the author shall be taken to be the person by whom arrangements necessary for the creation of the work are undertaken." A few other common law jurisdictions like Hong Kong, New Zealand, Ireland, India have followed this approach

The COP A also defines a computer-generated work as one generated by a computer in circumstances where there is no human author. What these provisions do is basically to broaden the concept of author in a way which is sufficient enough to subsume human beings that simply instigate and trigger the creation of the work. In other words the author will be considered the person who may have played no role at all in the actual production of the work.[153] The same approach can be adopted for Al-generated creations such that the author/inventor is the person who makes the arrangements for the creation of the work The question that arises is: who is the human being that made the necessary arrangements when it comes to Al-generated creations.

There has been an explosion of new forms of AI produced works that were not envisaged while incorporating the CO W-provision into the CDP A When that

[153] Enrico Bonadio, Luke McDonagh and Christopher Arvidsson, 'Intellectual Property Aspects of Robotics' (2018)
9(4) European Journal of Risk Regulation 655-676.

provision was drafted, there was little reflection on the reality of any form of AI technology.[154] Al-generated creations are made with little to no human input, leaving the question: who is "the person by whom the arrangements necessary for the creation of the work are undertaken" and more specifically, what does 'necessary arrangements' entail? Considering the question case by case could be one solution to see who is the person that is meant by the CDPA[155] The Court of Appeal decided on the authorship of a computer game in the decision of Nova Productions, and declared that a. player's input "is not artistic in nature and he has contributed no skill or labour of an artistic kind". It seems the CDPA the developer of the program as the first owner.[156] Dickenson states that looking at this decision, a way to approach who made the necessary arrangements is to identify the person that used their skill, labour and judgment in that arrangement.[157] The logical option would be the person who developed the AT-program. Granting of intellectual property rights to human owners, programmers or developers of Al machines in order to incentivize creation and innovation of autonomously generated AI works may lead to over expansion of AI works into copyright and patents. Given that AI may be able to autonomously generate further inventive ideas on its own (which general software is unable to do), the first-mover advantage of those owners of AI patents may be greater than that of other individuals with patents in general software or AI aided works which may be an atrophy to human

[154] Dickenson, 'Creative machines: ownership of copyright in content created by artificial intelligence applications' (2017) 39(8) E.l.P.R. 457.
[155] *Nova Productions v Mazooma Games [*2007] EWCA Civ 219.
[156] Julia Dickenson, 'Creative machines: ownership of copyright in content created by artificial intelligence applications' (2017) 39(8) E.l.P.R. p. 458 and 459.
[157] *Ibid.*

intelligence.[158] As a result, it would be worthwhile to consider shortening the duration of copyright or patent protection in autonomously generated AI works.[159]

Some scholars have proposed leaving such works - works generated autonomously by AI machine in the public domain, to serve as a valuable pool of inspiration, which creative individuals may use without fearing copyright or patent requirements.[160] This holds true especially for developing countries like Uganda which according to the 2007 ICTSD report, rely on acquisition of foreign owned technology and know-how to support industrial development. Uganda's 2007 communication to the WTO Council for TRIPS of priority Needs for Technical and Financial Cooperation emphasizes the importance of public domain as a source of knowledge building and technology absorption. Hence there is a need to recognize the importance of public domain in granting intellectual property protection to Al-generated works because it is more reflective of Uganda's actual level of development and the needs of technological learning and increased innovation.[161] It might be worth to think about (re-) establishing the concept of "company inventions" which allows companies to name themselves as inventors. Under German Patent Law, this concept prevailed until 1936. The inventorship for companies might make it easier to deal with AI generated outcome where it is difficult to identify and to name an individual inventor in the patent application.[162]

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[158] World Economic Forum Artificial Intelligence, committed *to improving the state of the world; Artificial Intelligence Collides with Patent law* (White paper, REF 160418 - case 00048540, 2 0] 88

[159] Anne Lauber-Ronsberg & Sven Hermank, 'The Concept of authorship and inventorship under pressure: Does artificial intelligence shift paradigms?' (2019) 7(14) *Journal of Intellectual Property Law & Practice 578.*

[160] Petar Hristov, 'Works Generated by AJ - How Artificial Intelligence Challenges Our Perceptions of Authorship', (Master thesis, Tilburg University Law School 2017) 41

[161] United Nations Conference on Trade and Development, 'Development Dimensions of Intellectual Property in Uganda: Transfer of Technology, Access to Medicines and Textbooks', UNCTAD/PCB/2009/13.12.

[162] Anne Lauber-Ronsberg and Sven Hetmank, ' The concept of authorship and inventorship under pressure: Does artificial Intelligence shift paradigms? 2019 7(14)

Copyright

Mr. Kenneth Muhangi[163] noted that when dealing with AI, the question of authorship cannot be answered in the traditional sense. This is owing to the fact that AI currently lacks legal personality to own copyright or to have capacity to contract. Currently none of Uganda's laws allow Al to own copyright or any intellectual property because our laws do not consider AI to have legal personality. AI is built from code the same way DNA is the building block of humans. Humans are self-conscious and aware. The self-awareness and ability of humans to ask themselves who they are and what their purpose is, is the test that is used to determine consciousness.

Kakungulu Mayambala[164] noted that if it is considered that choices are what make a human being as existential, philosophers argue, AI does not have such attributes.[165] AI makes choices but those choices are guided by what has been coded. Technology has not yet reached at a point where AI is able to create code on its own, or instances where AI evolves that it does not need a human programmer. If AI is created with algorithms that allow it to learn on its own, obtain attributes of humanity and reaches a point of consciousness, then we can have another discussion but that time has not come.

The Ugandan Copyright and Neighbouring Rights Act 2006 in its current form only protects work that is created by someone with legal personality. However, it should be remembered that AT goes beyond copyright. Copyright protects expression, and it is inherent. With AI, one is looking at sophisticated systems and processes. AI would fall under the industrial properties Act under patents and utility models if there is an element of inventive step which AI will be able to attain

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163 Interview with Kenneth Muhangi, Managing Partner, KTA Advocates (Kampala, Uganda 4 July 2020)

164 Interview with Ronald Kakungulu Mayambala, School of Law, Makerere University (Kampala, Uganda, 14 July 2020)

165 Jean-Paul Sartre (Edited by Stephen Priest), *Jean-Paul Sartre: Basic Writings, Routledge*, (2001)

once it achieves consciousness. There is a need to develop a sui generis regime that focuses on AI giving it some form of legal personality analogous to the corporate personality existing under the Companies Act. This sui generis regime can deal with AI and computer-generated works. Computer-generated works are already included under our Copyright Act under software as subject matter eligible for copyright protection. However, section 5 of the Act which protects software as subject matter eligible for copyright protection only protects AI algorithms or software protocols that underpin AI rather that the output which is the work generated by AI. Therefore, there is need to amend the Act so as provide for copyright protection in computer generated works.

There is a need to either amend the existing law or to come up with a sui generis regime for Artificial intelligence because the copyright act of 2006 in its current state does not provide copyright protection to AI. He stated that the existing copyright law does not carter for infringement on copyright programs and software.

Muhangi noted that copyright assigns economic and moral rights to the owner of copyright. The question is whether AI is eligible for these rights. Economic rights are limited to natural and legal/juristic persons whereas moral rights have always been granted to natural persons. Therefore, AI does not own economic and moral rights since it lacks both natural and legal personality to be eligible for economic rights and lacks natural personality to be eligible for moral rights. Therefore, AI would not be able to enforce these rights in case of infringement. When it comes to Neighbouring rights, there might be an issue of AI being able to enter into contractual relationship. This is owing to the fact that AI has no legal status to contract. Under the current law, computer generated works have a shorter copyright protection period compared to other works protected under copyright law.

Patents

It was generally considered that AI works can meet the requirements of patent law. Replacing a person skilled in the art with an AI system should be considered if AI is able to skill itself to be an expert in a particular field. Currently, a person skilled in the art is an individual but putting that aside, AI would qualify to be a person skilled in the art.

The right to be named as the inventor should be restricted to a human being until we reach the point where AI is fully autonomous. That whereas proactive legislation is usually helpful, amending Ugandan laws for now may be problematic. Rather, the country should start preparing sui generis legislation because AI is already creating. That more research should be carried out so that we fully know what AI is capable of i.e., whether it is capable of being autonomous.

According to Kabakubya,[166] AI has been a bedrock of innovation in the recent past and IP is very important in protecting and incentivizing innovation. Kayondo[167] suggested that one of the aspects that should be introduced in IP is regulatory sandboxes that allow aspects like Al where you have legislations within a framework. AI creates and then policymakers work backwards and look through that environment and give them certain considerations. For example, AI inventions should be owned by human beings or it should be owned by Al-machine where it can demonstrate that it can innovate on its own. That allows innovators to create within that free regulatory environment knowing that they are not doing something illegal. In other words, using an evidence-based approach to regulation in order to identify whether AI should be covered under sui generis regime or any existing legislation.

The EU Commission of 2017 rejected granting legal personality to AI because moral rights that cannot be attributed to it. The European parliament had called for sophisticated autonomous AI to be granted personhood under what it called "electronic personality". A group of experts published an open letter calling upon the commission to ignore the Parliament's move and reject "electronic personality". The principal argument made in the open letter, was that such personhood was not

[166] Interview with Solomon Kabakubya Buyinza, Founder, App about, Kampala (Kampala, Uganda, 4 July 2020)
[167] Interview with Silver Kayondo, Partner, Ortus Advocates, (Kampala, Uganda, 14 July 2020)

necessary to meet liability concerns which artificial gave rise to. The question of legal personality is crucial in attributing legal personality since under patent law, it is only natural persons who are recognized as inventors. AI has no natural or legal personality to be granted inventorship rights.

AI is created out of human endeavor. That it would therefore be wrong to assign ownership rights to AI when there is its human developer. This would dis-incentivize AI creators. It is important to note that under Uganda's patent law, ownership rights flow directly from inventorship unlike under copyright law where the author and owner may be different persons. Therefore, the question of ownership of Al-generated inventions would be determined by the inventor. It was also determined during the virtual meeting that patent rights necessitate the owner to be liable and responsible for anything arising out of the scope of the patentable subject matter. It would therefore be difficult to grant AI ownership rights since it would not solve the question of who would be responsible in case of liability.

Computer programs are not patentable under the Industrial Property Act of 2014. Professor Mayambala stated that under Article 52 of the EPO, computer programs are not patentable but can be if they show technical character. He made a case for the need to revise the Industrial Property Act to allow software and programs to be patentable.

Kabakubya and Muhangi both considered that AI may develop consciousness in future and therefore be regarded as human. Muhangi proposed the adoption of a sui generis regime governing legal personality of AI, the same as that governing Company law. This would also carter for key AI techniques like deep learning, where AI is able to generated work without human supervision. That IP rights of AI in years to come should be dealt with on a case-by-case basis.

The United States of America

The US Copyright Act does not explicitly require human authorship. The Act protects 'original works of authorship' However, the US Court of Appeal in the notorious monkey **selfie case** affirms the position that only humans are entitled to copyright protection. In that case, a UK Wildlife photographer, David Slater had in July 2011, visited a wildlife park in Indonesia to take unique pictures of some rare macaque monkeys. At some point, he intentionally left his camera on a tri pod for monkeys to explore as they seemed curious. One of the monkeys named Naruto, took the camera and snapped "selfies" of itself. David Slater then went on to print and publish several copies of the pictures. An animal rights group, Peoples for the Ethical Treatment of Animals (PET A) sued Slater in 2015 on behalf of Naruto for copyright infringement.[168] The Ninth Circuit Court of Appeals upholding the judgement of the lower court dismissed the appeal by PETA and held that copyright protection cannot be granted to animals, being a non-human entity. This case clearly reinforces the general rule that non-human entities such as Al and other machines, are not entitled to copyright protection.

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[168]*Naruto v Slater* No. L5-15469 (9thcir.2018).

[169]35 U.S.CS100(t).

[170]Suzan Y.Tulland Paula E. Miller, Patenting Artificial Intelligence: Issues of obviousness, Inventorship and Patent
Eligibility', (2018) 5(1) *Journal of Robotics, Artificial intelligence &Law318.*

automatically without any creative input or intervention from a human author.[171] The consequence is that these creations fall into public domain.

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In the UK legal system, Section 9(3) of the Copyright Designs and Patents Act 1988 provides that "in the case of a literary, dramatic, musical or artistic work which is computer-generated, the author shall be taken to be the person by whom the arrangements necessary for creation of the work are undertaken". The important aspect of this provision is that it requires a human actor who makes the necessary arrangements in coming up with computer generated works. In the Nova productions case[173], the court of appeal had to decide on the authorship of a computer game. The court declared that the user's input "is not artistic in nature and he has contributed no skill or labor of an artistic kind". This case suggests that a way to identify who made the necessary arrangements is to look at the person who used skill, labor and judgment in that arrangement. The court ruled in favor of the programmer. The above stated provision is therefore an emanation of Ada Lovelace's understanding that a machine "can do (only) whatever we know how to order it perform".

[171]U.S. Copyright Office, Compendium of U.S. Copyright Office Practices S10I(3ded.2017), section 3.13.2)

[172]A. Michel, 'Al-Generated creations: Challenging the traditional concept of Copyright'. 48.

[173]*Ibid 52*

In conclusion, the UK Copyright Designs and Patents Act 1988 is one of the pieces of legislation that recognize that non-human entities can generate copyright works with little or no human intervention as opposed to the position in US & Uganda which only recognize copyright works made by human authors. It therefore appears to be the more sensible approach of granting copyright protection to AI generated works. However, it can be stated that CDPA does not solve the dilemma of ascertaining true authorship in AI autonomously generated works since it is based on the incorrect supposition that the computer is no more than a tool for the programmer or a person responsible for making arrangements necessary for the creation of the work to be undertaken. The CDP A does not envisage generation of autonomously generated Al works without the person who makes the necessary invention. In regards to Uganda's copyright law, it can be asserted that the law is not ready for the era of Artificial Intelligence since it does not provide protection for work generated by AI without any human interfere

In the UK, section 7(3) of the 1977 Patent Act defines what constitutes an inventor. It states that an inventor means the actual deviser of the invention. Section 13(2) requires the applicant (in cases where the applicant is not the inventor) to identify the "person or persons whom he believes to be the inventor or inventors". In the application for a patent by Stephen Thalerl[174] where he sought to register an Artificial Intelligence machine called "DABUS" as the inventor, one of the questions considered was whether a non-human inventor can be regarded as an inventor under the Act. The UK patent office held that:

"... there is a clear expectation that the inventor and person for purpose of section 7 and 13 respectively are one and the same, namely a natural person - a human and not an AI machine. There has never been any indication from the courts that this is an incorrect interpretation and it is settled law that an inventor cannot be a corporate body. Even though the invention itself is said to have been created by DABUS, the applicant acknowledges that DABUS is an AI machine and not a human, so cannot be taken to be a "person" as required by the Act ... It is thus not for the Office to take an interpretation of the law that was not intended upon

[174]BL*01741/19.*

implementation and where there have been no indications from the courts or legislature that a "person" should be construed as anything other than a natural person. Since DABUS is a machine and not a natural person, I find that it cannot be regarded as an inventor for purposes of section 7 and 13 of the Act."

In the DABUS case, the patent office observed that the fundamental function of the patent system is to encourage innovation by granting time-limited monopolies in exchange for public disclosure. The office also observed that patent system did not cater for inventions created by machines and that it was never anticipated that it would. The office, on the other hand, recognized that times had changed and technology had advanced and called for the issue to be debated more widely and changes to the law be considered in the context of the debate rather than shoe homing Al inventorship into existing legislation. In the case of Uganda, it is apparent that patent law does not provide for protection of works autonomously generated by AI as it only recognizes human inventorship. Therefore, Uganda's patent law is not ready for the era of Artificial intelligence. Any changes would need to be debated across the world-wide divide so that patent laws can be harmonized. WIPO has led consultations in member countries to address how intellectual property law like patents can be updated to provide for Artificial intelligence generated creations. However, any recommendations should aim at furthering IP objectives to incentivize creation and innovation.

The UK approach offers a more pragmatic solution to the question of authorship and inventorship in Al-generated creations. Section 9(3) of the CDPA provides that "in the case of a literary, dramatic, musical or artistic work which is computer-generated, the author shall be taken to be the person by whom arrangements necessary for the creation of the work are undertaken." A few other common law jurisdictions like Hong Kong, New Zealand, Ireland, India have followed this approach

The COP A also defines a computer-generated work as one generated by a computer in circumstances where there is no human author. What these provisions do is basically to broaden the concept of author in a way which is sufficient enough to subsume human beings that simply instigate and trigger the creation of the work. In other words, the author will be considered the person who may have played no role at all in the actual production of the work.[175] The same approach can be adopted for Al-generated creations such that the author/inventor is the person who makes the arrangements for the creation of the work The question that arises is: who is the human being that made the necessary arrangements when it comes to Al-generated creations.

There has been an explosion of new forms of AI produced works that were not envisaged while incorporating the CO W-provision into the CDP A When that provision was drafted, there was little reflection on the reality of any form of AI technology.[176] Al-generated creations are made with little to no human input, leaving the question: who is "the person by whom the arrangements necessary for the creation of the work are undertaken" and more specifically, what does 'necessary arrangements' entail? Considering the question case by case could be one solution to see who is the person that is meant by the CDPA[177] The Court of Appeal decided on the authorship of a computer game in the decision of Nova Productions, and declared that a. player's input "is not artistic in nature and he has contributed no skill or labor of an artistic kind". It seems the CDPA the developer of the program as the first owner.[178] Dickenson states that looking at this decision, a way to approach who made the necessary arrangements is to identify the person that used their skill, labor and judgment in that arrangement.[179] The logical option would be the person who developed the AT-program.

Granting of intellectual property rights to human owners, programmers or developers of Al machines in order to incentivize creation and innovation of autonomously generated AI works may lead to over expansion of AI works into

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[175]Enrico Bonadio, Luke mcdonagh and Christopher Arvidsson, 'Intellectual Property Aspects of Robotics' (2018)
9(4) European Journal of Risk Regulation 655-676.

[176]Dickenson, 'Creative machines: ownership of copyright in content created by artificial intelligence applications' (2017) 39(8) E.l.P.R. 457.

[177]*Nova Productions v Mazooma Games* [2007] EWCA Civ219.

[178]Julia Dickenson, 'Creative machines: ownership of copyright in content created by artificial intelligence applications' (2017) 39(8) E.l.P.R. p.458 and 459.

[179]*Ibid.*

copyright and patents. Given that AI may be able to autonomously generate further inventive ideas on its own (which general software is unable to do), the first-mover advantage of those owners of AI patents may be greater than that of other individuals with patents in general software or AI aided works which may be an atrophy to human intelligence.[180] As a result, it would be worthwhile to consider shortening the duration of copyright or patent protection in autonomously generated AI works.[181]

Some scholars have proposed leaving such works - works generated autonomously by AI machine in the public domain, to serve as a valuable pool of inspiration, which creative individuals may use without fearing copyright or patent requirements.[182] This holds true especially for developing countries like Uganda which according to the 2007 ICTSD report, rely on acquisition of foreign owned technology and know-how to support industrial development. Uganda's 2007 communication to the WTO Council for TRIPS of priority Needs for Technical and Financial Cooperation emphasizes the importance of public domain as a source of knowledge building and technology absorption. Hence there is a need to recognize the importance of public domain in granting intellectual property protection to Al-generated works because it is more reflective of Uganda's actual level of development and the needs of technological learning and increased innovation.[183] It might be worth to think about (re-) establishing the concept of

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[180]World Economic Forum Artificial Intelligence, committed *to improving the state of the world; Artificial*
Intelligence Collides with Patent law (White paper, REF 160418- case00048540

[181]Anne Lauber-Ronsberg &Sven Hermank, 'The Concept of authorship and inventorship under pressure: Does artificial intelligence shift paradigms?' (2019) 7(14) *Journal of Intellectual Property Law & Practice 578.*

[182]Petar Hristov, 'Works Generated by AJ- How Artificial Intelligence Challenges Our Perceptions of Authorship', (Master thesis, Tilburg University Law School 2017)41

[183]United Nations Conference on Trade and Development, 'Development Dimensions of Intellectual Property in Uganda: Transfer of Technology, Access to Medicines and Textbooks', UNCTAD/PCB/2009/13.12.

"company inventions" which allows companies to name themselves as inventors. Under German Patent Law, this concept prevailed until 1936. The inventorship for companies might make it easier to deal with AI generated outcome where it isdifficult to identify and to name an individual inventor in the patent application.[184]

IN A UGANDAN CONTEXT

When dealing with AI, the question of authorship cannot be answered in the traditional sense. This is owing to the fact that AI currently lacks legal personality to own copyright or to have capacity to contract. Currently none of Uganda's laws allow Al to own copyright or any intellectual property because our laws do not consider AI to have legal personality. AI is built from code the same way DNA is the building block of humans. Humans are self-conscious and aware. The self-awareness and ability of humans to ask themselves who they are and what their purpose is, is the test that is used to determine consciousness.

Kakungulu Mayambala[185] noted that if it is considered that choices are what make a human being as existential, philosophers argue, AI does not have such attributes.[186] AI makes choices but those choices are guided by what has been coded. Technology has not yet reached at a point where AI is able to create code on its own, or instances where AI evolves that it does not need a human programmer. If AI is created with algorithms that allow it to learn on its own, obtain attributes of humanity and reaches a point of consciousness, then we can have another discussion but that time has not come.

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[184]Anne Lauber-Ronsberg and Sven Hetmank, 'The concept of authorship and inventorship under pressure: Does artificial Intelligence shift paradigms? 2019 7(14) *Journal of Intellectual Property Law & Practice 578*

[185]Interview with Ronald Kakungulu Mayambala, School of Law, Makerere University (Kampala, Uganda, 14July
2020)

[186]Jean-Paul Sartre (Edited by Stephen Priest), *Jean-Paul Sartre: Basic Writings,* Routledge, (2001)

The Ugandan Copyright and Neighboring Rights Act 2006 in its current form only protects work that is created by someone with legal personality. However, it should be remembered that AT goes beyond copyright. Copyright protects expression, and it is inherent. With AI, one is looking at sophisticated systems and processes. AI would fall under the industrial properties Act under patents and utility models if there is an element of inventive step which AI will be able to attain once it achieves consciousness. There is a need to develop a sui generis regime that focuses on AI giving it some form of legal personality analogous to the corporate personality existing under the Companies Act. This sui generis regime can deal with AI and computer-generated works. Computer-generated works are already included under our Copyright Act under software as subject matter eligible for copyright protection. However, section 5 of the Act which protects software as subject matter eligible for copyright protection only protects AI algorithms or software protocols that underpin AI rather that the output which is the work generated by AI. Therefore, there is need to amend the Act so as provide for copyright protection in computer generated works.

There is a need to either amend the existing law or to come up with a sui generis regime for Artificial intelligence because the Copyright and neighboring Act of 2006 in its current state does not provide copyright protection to AI. He stated that the existing copyright law does not carter for infringement on copyright programs and software.

Muhangi noted that copyright assigns economic and moral rights to the owner of copyright. The question is whether AI is eligible for these rights. Economic rights are limited to natural and legal/juristic persons whereas moral rights have always been granted to natural persons. Therefore, AI does not own economic and moral rights since it lacks both natural and legal personality to be eligible for economic rights and lacks natural personality to be eligible for moral rights. Therefore, AI would not be able to enforce these rights in case of infringement. When it comes to Neighboring rights, there might be an issue of AI being able to enter into contractual relationship. This is owing to the fact that AI has no legal status to contract. Under the current law, computer generated works have a shorter copyright protection period compared to other works protected under copyright law.

It was generally considered that AI works can meet the requirements of patent law. Replacing a person skilled in the art with an AI system should be considered if AI is able to skill itself to be an expert in a particular field. Currently, a person skilled in the art is an individual but putting that aside, AI would qualify to be a person skilled in the art.

The right to be named as the inventor should be restricted to a human being until we reach the point where AI is fully autonomous. That whereas proactive legislation is usually helpful, amending Ugandan laws for now may be problematic. Rather, the country should start preparing sui generis legislation because AI is already creating. That more research should be carried out so that we fully know what AI is capable of i.e., whether it is capable of being autonomous.

According to Kabakubya,[187] AI has been a bedrock of innovation in the recent past and IP is very important in protecting and incentivizing innovation. Kayondo[188] suggested that one of the aspects that should be introduced in IP is regulatory sandboxes that allow aspects like Al where you have legislations within a framework. AI creates and then policymakers work backwards and look through that environment and give them certain considerations. For example, AI inventions should be owned by human beings or it should be owned by Al-machine where it can demonstrate that it can innovate on its own. That allows innovators to create within that free regulatory environment knowing that they are not doing something illegal. In other words, using an evidence-based approach to regulation in order to identify whether AI should be covered under sui generis regime or any existing legislation.

The EU Commission of 2017 rejected granting legal personality to AI because moral rights that cannot be attributed to it. The European parliament had called for

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[187]Interview with Solomon Kabakubya Buyinza, Founder, App About, Kampala (Kampala, Uganda, 4July2020)

[188]Interview with Silver Kayondo, Partner, Ortus Advocates, (Kampala, Uganda, 14July2020)

sophisticated autonomous AI to be granted personhood under what it called "electronic personality". A group of experts published an open letter calling upon the commission to ignore the Parliament's move and reject "electronic personality". The principal argument made in the open letter, was that such personhood was not necessary to meet liability concerns which artificial gave rise to. The question of legal personality is crucial in attributing legal personality since under patent law, it is only natural persons who are recognized as inventors. AI has no natural or legal personality to be granted inventorship rights.

AI is created out of human endeavor. That it would therefore be wrong to assign ownership rights to AI when there is its human developer. This would dis-incentivize AI creators. It is important to note that under Uganda's patent law, ownership rights flow directly from inventorship unlike under copyright law where the author and owner may be different persons. Therefore, the question of ownership of Al-generated inventions would be determined by the inventor. It was also determined during the virtual meeting that patent rights necessitate the owner to be liable and responsible for anything arising out of the scope of the patentable subject matter. It would therefore be difficult to grant AI ownership rights since it would not solve the question of who would be responsible in case of liability.

Computer programs are not patentable under the Industrial Property Act of 2014. Professor Mayambala stated that under Article 52 of the EPO, computer programs are not patentable but can be if they show technical character. He made a case for the need to revise the Industrial Property Act to allow software and programs to be patentable.

Kabakubya and Muhangi both considered that AI may develop consciousness in future and therefore be regarded as human. Muhangi proposed the adoption of a sui generis regime governing legal personality of AI, the same as that governing Company law. This would also carter for key AI techniques like deep learning, where AI is able to generated work without human supervision. That IP rights of AI in years to come should be dealt with on a case-by-case basis.

Uganda is a member of the World Trade Organization (WTO).[189] As a member of the WTO, it is a signatory to the 1994 Agreement on Trade-Related Aspects of intellectual property (TRIPS Agreement).[190] The TRIPS Agreement applies to both copyright and patent law. The Agreement lays down minimum standards for the protection of intellectual property amongst WTO members.

The Agreement sets these standards by requiring that the substantive obligations of the main conventions of the WIPO, the Paris Convention and the Berne convention in their most recent versions be complied with.[191] Article 3 of the TRIPS mandates upon member states to 'accord to the nationals of other members treatment no less favourable than that it accords to its own nationals with regard to the protection of intellectual property'. It basically mandates parties to the Agreement to provide copyright to works by non-nationals on equal and similar terms as they do to nationals (national treatment). This therefore means that the copyright Act of Uganda applies to other non-nationals as it applies to Ugandans. However, it is important to consider whether the Act protects Al-generated works. Failure to do so may prompt other nationals to license AI-generated works in other countries that protect AI-generated works.

The TRIPS Agreement is silent as to whether the author of copyright has to be a legal or natural person. This position appears contradictory since the Agreement relies on criteria in Article 3 of the Berne Convention, which only recognizes natural persons.[192] Uganda is not party to the international instrument

[189]WTO Agreement: Marrakesh Agreement Establishing the World Trade Organization, 15April 1994, 1867UNTS
154,33 ILM 1144.

[190]Agreement on Trade-Related Aspects of Intellectual Property Rights, IS April 1994, Marrakesh Agreement
Establishing the World Trade Organization, Annex ic (1994) 1869UNTS 299,33TLM1197.

[191]WTO, 'Overview: The TRIPS Agreement', *https: llwww.wto.org/english / tratop*e/trips e/intei2 e.htm accessed April 22 2020.

[192]Herman Tuhairwe and Maureen Kemigabo, *'To* what extent does Uganda's Copyright and Neighbouring Rights Act

regulating Copyright law known as the Berne Convention for the Protection of Literary and Artistic Works (hereinafter, 'Berne Convention'). Even so, its criteria for eligibility of protection of copyright was incorporated in TRIPS, and to this extent, it is relevant to non-parties like Uganda.

Article 10(1) of the TRIPS provides that computer programs are protected as literary works. Furthermore, data compilations whether in machine-readable or other form, which by reason of selection or arrangement of their contents constitutes intellectual creations are protected as such, even though this protection does not extend to data itself.

Article 9(2) of the TRIPS expressly states that copyright protection shall extend to expressions and not to ideas, procedures, methods of operation or mathematical concepts as such. This means that AI algorithms cannot be copyrightable or patentable since they are mathematical methods.

Uganda is also party to the WIPO convention which is a multilateral treaty that establishes the World Intellectual Property Organization. WIPO is a global forum for intellectual property (IP) services, policy, information and cooperation which aims at developing a balanced and effective international IP system that enables innovation and creativity. On September 27 2019, WIPO held its first Conversation on IP and AI bringing together member states and other stakeholders to discuss the impact of Al on IP policy, with a view to collectively formulating the questions that policymakers need to ask. This has been followed by a public consultation process on artificial intelligence (AI) and intellectual property (IP) policy, inviting feedback on an issues paper designed to help define the most-pressing questions likely to face IP policy makers as AI increases in importance.[193]

2006 incorporate the TRIPS Agreement's standards?' 2019, Vol. 14, No.6, Journal of Intellectual Property Law& Practice, 456

[193]WFPO, 'impact of Artificial Intelligence on IP policy 'https: llwww.wipo.intjabout-ip/enlartificialintelligence/call for comments accessed April 22,2020.

CHAPTER SEVEN

Intellectual Property in Ai

COPYRIGHT LAW IN AI

There are two ways in which copyright law can deal with works where human interaction is minimal or non-existent. It can either deny copyright protection for works that have been generated by a computer hence contributing to the public domain or it can attribute authorship of such works to the creator of the program.

The Copyright and Neighboring Rights Act of Uganda 2006 provides that computer programs are eligible for copyright protection[194]. This caters for AI software programs as long as they satisfy the requirements for copyright protection i.e., originality. However, although the act protects AI computer programs, it does not cater for works autonomously generated by AI programs. Uganda's current copyright law on authorship only allows human authorship and updating the law to grant person-hood to Al for purposes of authorship does not look a probable option because it does not solve the question of who grants licenses nor who would enforce the IP rights in case of infringement. Basically, IP rights should be allocated in such a way as to provide for an incentive to invest in the development of AI. Granting copyright to the person who made the operation of artificial intelligence possible seems to be the most sensible approach, with the UK's model looking the most efficient. Such an approach will ensure that companies keep investing in the technology, safe in the knowledge that they will get a return on their investment.

[194]Section 5ofthecopyright and Neighbouring rightsact2006.

However, on the other hand, developing countries like Uganda that have weak domestic scientific and technological base, relying on acquisition of foreign-owned technology and know-how to support industrial development, the public domain can be utilized for technological learning and incremental innovation. Whether this is a desirable option, largely depends on the economic assessment. Copyright law should seek to strike an appropriate balance between incentives for innovators and avenues for competitors to access technology-relevant information. Whereas it can be argued that leaving AI-generated works unprotected will diminish the incentives to invest and develop AI technologies, the public domain can also be seen as a balancing counterweight to copyrights over expansion as well as an important inspiration for human creativity. First, works created by AI when left in the public domain will serve as a valuable pool of inspiration, which creative individuals may use without fearing copyright infringements. Additionally, given AI's potential for unlimited creation of works, if these works were protected, it is easy to imagine a rapid and unbalanced growth in Al-generated copyright protected works which may ultimately hinder free imitation and creation.

Patents Law In Ai

Since AI cannot claim inventorship rights in autonomously generated creations, it would be futile to amend the law to provide for AI as the inventor in Al-generated creations. This is because the inventive capacity by AI may not be disclosed during application for patents and humans may list themselves as inventors as has happened before with Thaler's creative machine. Alternatively, it has been argued that AI is incapable of being incentivized to innovate and only does that which it is taught or has learnt to do. Therefore, the most practical approach may be to vest inventorship in Al-generated creations in the inventor who has developed the program creating the AI. This would encourage further investment and innovation in AI programs that autonomously generate works.

Countries like Uganda at an early stage of technological development depend to a great extent on informal means of technology transfer by imitation, reverse engineering and, at a more advanced stage, adaption to local conditions.[195] Accordingly, Uganda's 2007 Communication to the WTO Council for TRIPS of Priority Needs for Technical and Financial Cooperation emphasizes the importance of the public domain as a source of knowledge building and technology absorption[196]. Therefore, this study advocates for the need to adopt the level of intellectual property protection that are reflective of Uganda's actual level of development and the needs for technological learning, and incremental innovation. Hence, this book recommends the need to recognize the importance of public domain in regulating Artificial Intelligence in Uganda. Therefore, it would be worthwhile to expand Uganda's public domain by making reforms to patent law so that local innovators who rely on information available in the public domain can access technologically- relevant information. These local innovators should be granted some form of protection to prevent competitors from wholesale copying of their inventions by using second tier categories of IPRs such as utility models or trade secrets since they generate less impact on the public domain.[197]

Sections 10(2) and (3) lay down a strict novelty standard, providing that any written or oral prior art publicly available in any country of the world shall destroy the novelty of an invention claimed in Uganda. By restricting the possibilities to claim existing inventions as new, this section contributes to the safeguarding of a public domain needed for domestic researcher's freedom to operate.[198] In order to preserve in the public domain technological developments that are predictable from existing prior art, section 11 that provides for the inventive step standard should be amended to specify that the assessment of non-obviousness of the invention need not be based on a local person skilled in the art,

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[195]United Nations Conference on Trade and Development, 'Development Dimensions of Intellectual Property in Uganda: Transfer of Technology, Access to Medicines and Text books', UNCTAD/*PCB/2009113.l2.*

[196]*Ibid*

[197]United Nations Conference on Trade and Development, 'Development Dimensions of Intellectual Property in
Uganda: Transfer of Technology, Access to Medicines and Textbooks', UNCTAD/*PCB/2009113.13.*

[198]*Ibid 13.*

but rather on skills existing anywhere in the world. This would contribute to the development of AI technology by preserving public domain.[199]

This book proposes that a sui generis regime governing legal personality of AI, the same as that governing Company law, be adopted in Intellectual property law to carter for key AI techniques like deep learning, where AI is able to generated work without human supervision. This is based on the fact that most AI may in future acquire the ability to act autonomous without a human programmer. The law should be proactive to carter for such future eventualities.

Current intellectual property laws are not well suited to deal with the issue of ownership of potential intangible assets autonomously created by artificial intelligence technology. Although a number of solutions are possible, the sensible and pragmatic approach is for ownership to sit with the person who commissioned the assets. The implications of the suggested ownership solution have to be carefully thought through, because it is inextricably linked with the question of who is accountable when fully autonomous AI causes accidents.

INTANGIBLE ASSETS AND AUTONOMOUS AI

Intellectual property rights are intangible assets, in other words assets that we can own, buy and sell, but which are not physical things. Intellectual property rights include trademarks, designs, copyright, trade secrets, patents and others. Potential intangible assets created by autonomous AI can include innovative technology, software, art works, confidential information and other things, which IP rights would protect if a human had created them. For purposes of this insight paper, we consider autonomous AI to involve machines acting outside the control of humans, Intellectual property law needs to catch up

Current IP laws are not well suited to deal with the situation where autonomous AI creates potential intangible assets, because in many cases those assets can only arise if there is a human creator. Patent law generally considers the inventor as the first owner of the invention. The inventor is the person who creates the invention. In

[199] Ibid 14

the case of autonomous AI generating an invention, there is no legal owner as the AI technology cannot own the invention.

Intellectual property laws and systems establish rules about who owns which intangible rights. These rules have generally been developed and introduced to facilitate commerce and trade as parties can buy, sell and license rights in a way that is generally clear to them. There are also well-established ways of resolving disputes about the intangible rights. Another argument supporting intangible intellectual property rights is that they stimulate research and innovation. The cost of research is high and investors will not pay that cost without a reasonable chance of a return on their investment. The laws and systems enabling these intangible rights to exist are sometimes complex and expensive. However, the prospect of not having intellectual property rights is one of chaos and uncertainty, which is bad for business and the economy.

The current IP laws and systems do not offer an answer to a situation where IP rights cannot protect assets that are a product of autonomous AI. It is also not sensible or practical to continue with an approach where no one owns the potential intangible assets created. The situation is generally the same in many countries around the world. For instance, US law states that "Whoever invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof, may obtain a patent therefor, subject to the conditions and requirements of this title," which implies that a person needs to have made the invention, not a computer.

CHAPTER EIGHT

A Legal Person or a Child Under Artificial Intelligence?

Thinking about how we can adapt intellectual property laws to better cope with assets created by autonomous AI, one option is to enable the autonomous AI itself to own the intangible assets. Those who argue that giving autonomous AI the status of a legal person would address the issue of accountability, effectively imply this solution. The question of accountability is identifying who is responsible for things that go wrong because of the use of autonomously acting artificial intelligence technology.

If a fully autonomous robot, such as Rachel in Bladerunner, has the status of a legal person, then it follows that she can be an inventor and subsequent owner of a patent. In the same way, she could be the author of copyright in a computer program or the creator of a reputation, which gives rise to passing off rights for unregistered trade mark protection. Therefore, it seems impossible to answer the question of ownership of intangible assets created by fully autonomous AI without at the same time answering the question of accountability. The two issues are inextricably linked. However, it seems inappropriate to give autonomous AI the status of a legal person. Humans should have the ethical duty to take responsibility for any autonomous AI technology they commission, deploy or use.

Alternatively, future law could give autonomous robots a status akin to that of a child. A human would then be responsible for the robot in the same way a human parent or guardian is responsible for a child. This goes some way towards addressing the problem of accountability. A significant limitation of this

Approach is that the robot would own the intangible assets whereas the human parent or guardian would have very limited control.

IP for AI

IP relates to intangible assets, including inventions, brands, new technologies, source code and artistic works. More specifically, IP pertains to patents, trademarks, copyright and industrial design. IP also extends to trade secrets and confidential information.

In the AI context, the legislative protection has not yet advanced as quickly as the technology, which makes early and ongoing IP portfolio management of particular importance.

Patents

Patents provide a time-limited protection for an invention. A patent entitles the patent owner to the exclusive right to make, use and sell his or her invention in exchange for full and clear disclosure on how to work the invention.

Patents provide a mechanism to exclude others from making, using or selling the patented technology, which may help companies obtain or maintain market share, and protect research and development investments. Patents can provide a competitive advantage, and may also be used defensively as a negotiation tool. Patent publications can also be cited against subsequently filed applications to prevent grant.

Throughout its history the patent system has been evolving, expanding its patentable subject matter and adjusting its patentability standards to keep pace with technological development. However, with the emergence of modern technologies the patent system has encountered new challenges. In particular, such technologies as AI have brought new ways of inventing, which require only a limited involvement of a human. This has raised a range of important issues, with the key question of whether the patent system is still able to fulfil its objectives of incentivising and rewarding innovation. We believe that the advancement of AI technologies requires urgent adjustments to the patent system in order to avoid significant negative consequences of an unbalanced protection afforded to the outputs of AI activities, which in turn may result in harmful social, economic and ethical implications.[200]

A technology development strategy should consider if patent protection is available for core technology innovation. Companies should also be aware of other publications and litigations, as competitors and other players may have their own patents or pending applications. In contrast with trade secrets, granted patents may be enforced against third parties that make, use or sell the claimed invention, despite independent development. Given the quickly evolving AI market, obtaining early priority dates is important in view of the 'first to file' nature of the patent system.

Patent eligibility

AI involves software which is increasingly difficult to patent. Patent offices, along with the courts, have struggled with establishing clear delineations of what is patentable and what is not patentable. The claims have to clearly define the patent eligible innovation with the patent description clearly describing how to make and use the innovation. As an example, courts held that a method for automatically animating lip synchronisation and facial expressions to be patent eligible and specific inventive animation rules were described to enable a computer to do something it could previously.

Highlighting salient technical features such as technical advantages and practical implementation details can increase the likelihood of success during patent examination. The description should highlight discernible effects generated by the AI innovation or use case. An example can relate to moving a physical machine to pick up an object. The AI tool can also be embodied in a physical form factor, such as a medical device.

[200]Centre for the Fourth Industrial Revolution, *Artificial Intelligence Collides with Patent Law* (White Paper, 2018)

A company making, using or selling AI tools should also consider its freedom to operate to avoid encroaching on existing patents covering AI innovation. A patent landscape assessment is helpful to understand the scope of third-party rights to mitigate risk.

Given the importance of data analytics, companies continue to invest in research and develop in AI to advance their processing and data mining capabilities. An IP strategy for AI systems will layer IP rights to protect different aspects of the innovation. Companies can clearly define and protect their IP with registrations and documentation. Clear agreements on IP rights should be established between third parties to manage risk.

COMPUTER-GENERATED WORKS

A **computer** is a digital electronic machine that can be programmed to carry out sequences of arithmetic or logical operations (computation) automatically. Modern computers can perform generic sets of operations known as programs. These programs enable computers to perform a wide range of tasks. A **computer system** is a "complete" computer that includes the hardware, operating system (main software), and peripheral equipment needed and used for "full" operation. This term may also refer to a group of computers that are linked and function together, such as a computer network or computer cluster.

A broad range of industrial and consumer products use computers as control systems. Simple special-purpose devices like microwave ovens and remote controls are included, as are factory devices like industrial robots and computer-aided design, as well as general-purpose devices like personal computers and mobile devices like smartphones. Computers power the Internet, which links billions of other computers and users.

Early computers were meant to be used only for calculations. Simple manual instruments like the abacus have aided people in doing calculations since ancient times. Early in the Industrial Revolution, some mechanical devices were built to automate long tedious tasks, such as guiding patterns for looms. More sophisticated electrical machines did specialized analogue calculations in the early 20th century.

The first digital electronic calculating machines were developed during World War II. The first semiconductor transistors in the late 1940s were followed by the silicon-based MOSFET (MOS transistor) and monolithic integrated circuit (IC) chip technologies in the late 1950s, leading to the microprocessor and the microcomputer revolution in the 1970s. The speed, power and versatility of computers have been increasing dramatically ever since then, with transistor counts increasing at a rapid pace (as predicted by Moore's law), leading to the Digital Revolution during the late 20th to early 21st centuries.

Conventionally, a modern computer consists of at least one processing element, typically a central processing unit (CPU) in the form of a microprocessor, along with some type of computer memory, typically semiconductor memory chips. The processing element carries out arithmetic and logical operations, and a sequencing and control unit can change the order of operations in response to stored information. Peripheral devices include input devices (keyboards, mice, joystick, etc.), output devices (monitor screens, printers, etc.), and input/output devices that perform both functions (e.g., the 2000s-era touchscreen). Peripheral devices allow information to be retrieved from an external source and they enable the result of operations to be saved and retrieved.

Assessment With no counterpart in most jurisdictions, s9(3) of the Copyright, Designs and Patents Act 1988 (CDPA) is rather unique, if not problematic. Indeed, the effective operation of this provision may depend upon other aspects of copyright law which, following Brexit, remain unsettled. By providing 50-year protection to 'authorless' computer-generated literary, dramatic, musical or artistic (LDMA) works, s 9(3) poses the complex legal question of what originality standard should be applied. There is an apparent inconsistency with the EU standard of 'an author's own intellectual creation', which relies on creative choices made by an individual, for example. The standard of 'originality' applicable to computer-generated outputs that do not reflect human creative input is a matter for UK law alone. In more than 30 years, s 9(3) was only ever considered in a single court decision, which did not address the originality issue. Determining the author of computer-generated works—that is, the 'person by whom the arrangements necessary for the creation of the work are undertaken'—is no straightforward matter either. In Nova Productions, the Court of Appeal found such a person to be the author of the computer program rather than the user. However, this decision concerned a simple two-dimensional video game, offering limited guidance on the issue of AI-assisted outputs. Furthermore, as the experience with other types of subject matter (e.g., sound recordings) suggests, the notion of 'arrangements necessary' is not resolved, nor is it clear if the 'person' making such arrangements can be a legal entity (i.e. a firm). The introduction of a related right of reduced scope and duration referred to as option 2 may lead to an issue of cumulation, with the same subject matter attracting rights of different kind, as the recent experience with databases suggests. The potential costs of additional IP rights typically are of two kinds: higher prices and loss of innovation. In the UK, the Hargreaves (2011) and Gower (2006) Reviews recommended making the policy process more transparent and rigorous. IP rights, once created, have proved almost impossible to remove.

Patent Inventorship

An **invention** is a unique or novel device, method, composition or process. The invention process is a process within an overall engineering and product development process. It may be an improvement upon a machine or product or a new process for creating an object or a result. An invention that achieves a completely unique function or result may be a radical breakthrough. Such works are novel and not obvious to others skilled in the same field. An inventor may be taking a big step toward success or failure.

An **inventor** is a person who creates or discovers an invention. The word inventor comes from the Latin verb invenire, invent-, to find. Although inventing is closely associated with science and engineering, inventors are not necessarily engineers or scientists.[3]

Some inventions can be patented. The system of patents was established to encourage inventors by granting limited-term, limited monopoly on inventions determined to be sufficiently novel, non-obvious, and useful. A patent legally protects the intellectual property rights of the inventor and legally recognizes that a claimed invention is actually an invention. The rules and requirements for patenting an invention vary by country and the process of obtaining a patent is often expensive.

Another meaning of invention is **cultural invention**, which is an innovative set of useful social behaviours adopted by people and passed on to others. The Institute for Social Inventions collected many such ideas in magazines and books. Invention is also an important component of artistic and design creativity. Inventions often extend the boundaries of human knowledge, experience or capability. Inventions are of three kinds: scientific-technological (including medicine), socio-political (including economics and law), and humanistic, or cultural.

Scientific-technological inventions include railroads, aviation, vaccination, hybridization, antibiotics, astronautics, holography, the atomic bomb, computing, the Internet, and the smartphone.

Socio-political inventions comprise new laws, institutions, and procedures that change modes of social behaviour and establish new forms of human interaction and organization. Examples include the British Parliament, the US Constitution, the Manchester (UK) General Union of Trades, the Boy Scouts, the Red Cross, the Olympic Games, the United Nations, the European Union, and the Universal Declaration of Human Rights, as well as movements such as socialism, Zionism, suffragism, feminism, and animal-rights veganism.

Humanistic inventions encompass culture in its entirety and are as transformative and important as any in the sciences, although people tend to take them for granted. In the domain of linguistics, for example, many alphabets have been inventions, as are all neologisms (Shakespeare invented about 1,700 words). Literary inventions include the epic, tragedy, comedy, the novel, the sonnet, the Renaissance, neoclassicism, Romanticism, Symbolism, Aestheticism, Socialist Realism, Surrealism, postmodernism, and (according to Freud) psychoanalysis. Among the inventions of artists and musicians are oil painting, printmaking, photography, cinema, musical tonality, atonality, jazz, rock, opera, and the symphony orchestra. Philosophers have invented logic (several times), dialectics, idealism, materialism, utopia, anarchism, semiotics, phenomenology, behaviorism, positivis m, pragmatism, and deconstruction. Religious thinkers are responsible for such inventions as monotheism, pantheism, Methodism, Mormonism, iconoclasm, puritanism, deism, secularism, ecumenism, and the Bahá'í Faith. Some of these disciplines, genres, and trends may seem to have existed eternally or to have emerged spontaneously of their own accord, but most of them have had inventors.

IP regimes have been under the influence of emerging trends in the innovation ecosystem such as technological diffusion, decentralization of knowledge, increased innovation costs, and shorter innovation cycles (Gassmann et al., 2021). AI technologies have raised existential questions regarding the fundamental tenets of the patent system including ownership, inventorship, and infringement. The increasing autonomous nature of the AI technologies and emergence of possible products, which are solely manufactured by the AI systems, has raised the question about the suitability of these systems for inventorship in the current IP regime, which relies on the "human inventor" to incentivize people for innovation.

The term "AI-generated" refers to the products that are generated by AI without any human intervention (Bosher, 2020). In today's technology, AI systems have not the capability to produce a piece of art or goods in a completely autonomous way. However, rapid technological developments in this field force the IP policymakers to introduce ideal regulations that enable the protection of IP rights without creating any side-effect such as a decline in the enthusiasm for new inventions.

The main purpose of the current patent system is to grant exclusive rights to natural persons for their inventions. Because these rights are believed to be beneficial to encourage people and entities to make investments to contribute to their societies. Another goal of the patent system is to record the specific details of the inventions for inspiring future generations to develop this knowledge-based heritage.

The Rembrandt project, in which AI technology was used to produce a painting based on the data acquired from the previous paintings of Rembrandt, clearly demonstrates the blurriness between technology and art (Baraniuk, 2016).

In the context of AI, the crucial question is that who should be the inventor in the patent application for AI-generated products? According to a school of thought, AI-generated products should fall within the category of public domain. The main problem with this approach is that lack of incentives would harm the motivation of the people to invest in the development of new inventions (Gürkaynak et al., 2017). In this regard, granting the patent rights for the AI-generated products to the creator of AI systems are believed to be crucial in the entrepreneurial ecosystem. A similar approach is also adopted in the Taiwan legal system. Article 798 of the Taiwan Civil Code states that "Fruits that fall naturally on an adjacent land are deemed to belong to the owner of such land, except if it is a land for public use".

On the other hand, the shortfall of vesting IP rights to the AI systems is related to the licensing and transferring of these rights to the other actors. Because the AI systems do not have capability to give decisions about these issues. Current legal systems do not recognize a non-human actor as a candidate for inventorship. In addition to that, although the number of AI-generated products has increased in recent years, it is evident that such products cannot come to exist without massive human endeavours in the creation of AI algorithms.

In the Dabus case in the UK, Stephen Thaler alleged that the AI system should have been added as a sole name in the patent application of a neural flame and fractal container. Courts in the US, UK, and EU refused his claim on the ground that Dabus is not a natural person and demonstrated that judicial systems are not ready to embrace the idea of granting IP rights to the AI systems (Megget, 2021). Thaler also applied to EPO to register the new inventions on the name of the AI-based machine DABUS (EP 18 275 163 (for a food container.), and EP 18 275 174 (for methods and devices for attracting enhanced attention)). As considered himself as the employee of DABUS, He stated that "DABUS could identify the novelty of its own idea[s] before a natural person did" (Olivi and Spadavecchia, 2020). The EPO also rejected the application of Thaler based on Article 81 of the European Patent Convention (Sandys, 2020).

Apart from the inventorship dispute, there is another dispute about the liabilities in the IP infringement conducted by the AI systems. Lack of the mens rea element on the side of the inventor of the AI systems in those infringements will complicate the criminal proceedings (Bharucha & Partners, 2021).

Both legal experts and policymakers in Turkey closely follow the AI-related IP debates in the world. Turkish Patent Office sees AI technology as an industrial revolution known as Industry 4.0 due to the sharp increase in the number of AI patent applications.

Habip Asan, the head of the Turkish Patent Office, stated that "there is a 56-percent rise in the applications about the artificial intelligence and Industry 4.0 in the recent three years to European Patent Office" (Türk_Patent, 2018). Furthermore, Istanbul, Ankara, and Izmir Bars prepared a detailed report about the implications of AI on the Turkish patent regime and criminal law (KIZRAK et al., 2019). It should be noted that there has not been yet a consensus about the new IP regulations regarding the AI systems in Turkey.

In conclusion, it seems that the inventorship dispute regarding AI-generated products will remain in flux for the foreseeable future. For now, each AI-related IP dispute will be investigated based on the unique material facts of them. Different nations and international organizations including the UK, the US, EU, and WIPO are performing comprehensive studies to find optimum solutions for the IP disputes related to the AI-systems and the pace of the development in AI technology will be decisive in the creation of new rules in this field.

A recent EPO study notes that AI has been one of the fastest growing Fourth Industrial Revolution[201] (4IR) fields since 2011, with an average annual growth rate

[201] The Fourth Industrial Revolution is a term firstly used by Klaus Schwab, founder and Executive Chairman of the World Economic Forum, to designate the transformation being brought to our society by recent technological innovation in certain fields –notably AI but also robotics, he Internet of Things, autonomous vehicles, 3-D printing, nanotechnology, biotechnology, materials science, energy storage, and quantum computing are bringing to our society. According to the author The First Industrial Revolution used water and steam power to mechanize production. The Second used electric power to create mass production. The Third used electronics and information technology to automate production. Now a Fourth Industrial Revolution is building on the Third, the digital revolution that has been occurring since the middle of the last century. It is characterized by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres. In 'The Fourth Industrial Revolution, What It Means and How to Respond', Foreign affairs, December 12, 2015, https://www.foreignaffairs.com/articles/2015-12- 12/fourth-industrial-revolution.

of 43% and 83 patent applications in 2016 (EPO, 2017). However, the increased pace of patent applications is confronted with a number of legal uncertainties. A sample of patent-protection issues for AI that consistently appear across jurisdictions and societies are provided in this section. (i) Eligible subject matter for several years now, the courts have struggled with the issue of whether to grant patents in new fields of invention, particularly computer software (Kohlhepp, 2008). The eligibility of software, including AI software, to receive patent protection is an intricate issue. Generally, computer programs "as such" are excluded from patentability at the EPO (Article 52(2)(c) and (3) of the European Patent Convention (EPC)), but the exclusion does not apply to computer programs having a technical character (cf. producing a 'further technical effect' when run on a computer (as described in the Guidelines for Examination (GL) under section G – II 3.3.6)).

Throughout its history the patent system has been evolving, expanding its patentable subject matter and adjusting its patentability standards to keep pace with technological development. However, with the emergence of modern technologies the patent system has encountered new challenges. In particular, such technologies as AI have brought new ways of inventing, which require only a limited involvement of a human. This has raised a range of important issues, with the key question of whether the patent system is still able to fulfil its objectives of incentivising and rewarding innovation. We believe that the advancement of AI technologies requires urgent adjustments to the patent system in order to avoid significant negative consequences of an unbalanced protection afforded to the outputs of AI activities, which in turn may result in harmful social, economic and ethical implications.[202]

With the rapid evolution of AI technologies and the increase of their computational power, the process of inventing has undergone substantial changes. As AI is becoming more efficient in sorting data, finding patterns, and making predictions, these technologies are increasingly employed in various innovation-driven sectors. AI technologies have now reached such a level that they are capable of producing

[202] Centre for the Fourth Industrial Revolution, Artificial Intelligence Collides with Patent Law (White Paper, 2018)

outputs with only a limited involvement of a human. Such outputs, if they were produced by a human inventor, would be capable of attracting patent protection. This raises an important question of whether under the current patent law regime an AI system can be defined as the inventor. We believe that the answer to this question is negative. The patent system, including its rationale and the fundamental principles on which the patentability standards are based, are designed around a 'human inventor'. Thus, the primary justification of patent law is utilitarian, i.e., it is aimed at incentivising and rewarding innovative activities of inventors. The protection is provided to inventions that are the results of 'human ingenuity' and not merely to discoveries or an obvious extension or workshop variation of what was already known.

The concept of 'invention' entails the 'act of intellectual creation original to the inventor i.e., the mental act occurring in the mind of the inventor. Moreover, a dividing line between what is patentable and what is a mere extension of existing knowledge is also grounded on 'human capabilities' by comparing what the notional 'person skilled in the art' would have been able to discover without unusual effort and the additional step of human ingenuity made by the inventor.7 All these considerations evolve around the intellectual and creative activities of 'human inventors' and, thus, leave little space for 'non-human inventors. More specifically, the analysis of the matters related to inventorship is designed around a human inventor. When determining when an invention was created and by who, the courts generally focus on the ideas occurring in the mind of the inventor, i.e., conception of the invention.8 For example, in the UK, Section 7(2) of the Patents Act 1977 states that a patent will primarily be granted to the inventor or joint inventor and Section 13(1) requires that the inventor(s) have a right to be mentioned in any patent or any published application. The Patents Act, however, provides little assistance in determining who the inventor is and simply states in Section 7(3) that the inventor is the actual devisor of the invention. Interpreting this provision, the UK courts explained that the inventor is 'the natural person who "came up with the invention

nventorship and Ownership

In most cases, AI is a tool that assists inventors in the invention process or constitutes a feature of an invention. In these respects, AI does not differ radically from other computer-assisted inventions. However, it would now seem clear that inventions can be autonomously generated by AI, and there are several reported cases of applications for patent protection in which the applicant has named an AI application as the inventor. In the case of inventions autonomously generated by AI:

(i) Should the law permit or require that the AI application be named as the inventor or should it be required that a human being be named as the inventor? In the event that a human inventor is required to be named, should the law give indications of the way in which the human inventor should be determined, or should this decision be left to private arrangements, such as corporate policy, with the possibility of judicial review by appeal in accordance with existing laws concerning disputes over inventorship?

(ii) The inventorship issue also raises the question of who should be recorded as the owner of a patent involving an AI application. Do specific legal provisions need to be introduced to govern the ownership of autonomously generated AI inventions, or should ownership follow from inventorship and any relevant private arrangements, such as corporate policy, concerning attribution of inventorship and ownership?

(iii) Should the law exclude from the availability of patent protection any invention that has been generated autonomously by an AI application?

With the rapid evolution of AI technologies and the increase of their computational power, the process of inventing has undergone substantial changes. As AI is becoming more efficient in sorting data, finding patterns, and making predictions, these technologies are increasingly employed in various innovation-driven sectors. AI technologies have now reached such a level that they are capable of producing outputs with only a limited involvement of a human. Such outputs, if they were produced by a human inventor, would be capable of attracting patent protection. This raises an important question of whether under the current patent law regime an AI system can be defined as the inventor. We believe that the answer to this question is negative.

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The court in Yeda emphasised that it is not sufficient to merely contribute to the claims, because the claims may include non-patentable elements derived from the prior art. Therefore, a person will be considered as the inventor if they can demonstrate that they have contributed to the 'inventive concept'. Certain contributions are usually treated by the courts as being inventive (e.g., where a person contributed to the solution of a particular problem) and, thus, such a person will be considered as a (co)inventor. On the other hand, if a person merely contributed an 'unnecessary detail' to the invention, or the contribution was of a managerial, administrative or financial nature, such a contribution will not be considered inventive. Therefore, the touchstone in defining inventorship is the nature of the actual contribution to the conception of the invention, which must be creative or intelligent. This naturally excludes AI technologies from being identified as the inventor. While 'AI activity may be instrumental if not decisive to the patentability of an invention and the success of the latter in solving a technical problem', such technologies nevertheless cannot be considered as 'a deviser of the invention', because they are not capable of cognition (at least at present). Instead, these technologies should be seen as 'a crucial tool in arriving at the invention'.

As the modern level of technology requires certain human involvement in the inventing process of AI systems, we believe that the current patent law regime is capable of accommodating AI-generated inventions by attributing inventorship to a person who intellectually dominated over the inventive process. We also believe that at present there is no need to implement any changes to patent law in order to define an AI system as the inventor. Any such changes to the current legal framework are likely to disturb the rationale and the fundamental principles of the patent system discussed above. Should the technology progress to such a level, in which no human involvement would be required (the so-called 'strong AI'), then the mechanisms of protection for the outputs of such a technology would need to be reconsidered.

Obviousness Analysis Of Ai-Generated Inventions Requires Adjustments

A condition of patentability is that the invention involves an inventive step or be non-obvious. The standard applied for assessing non-obviousness is whether the invention would be obvious to a person skilled in the relevant art to which the invention belongs.

(i) In the context of AI inventions, what art does the standard refer to? Should the art be the field of technology of the product or service that emerges as the invention from the AI application?

(ii) Should the standard of a person skilled in the art be maintained where the invention is autonomously generated by an AI application or should consideration be given to replacing the person by an algorithm trained with data from a designated field of art?

(iii) What implications will be having an AI replacing a person skilled in the art have on the determination of the prior art base?

(iv) Should AI-generated content qualify as prior art?

The use of AI technologies in the inventing process raises another important question of whether the current approach to the obviousness analysis should be changed in relation to AI-generated inventions. We believe that the answer to this question should be affirmative. The current obviousness tests, as, for example, applied by the EPO and the UK courts,17 is deeply rooted in the assessment of human capabilities, i.e., their motivation to pursue certain routes, restricted by their abilities to analyse limited amount of options, predictability and expectation of success, etc. All these principles and concepts may become less relevant with respect to the inventive process with the use of AI.

While various jurisdictions have developed certain specific structured approaches to analysing obviousness, the fundamental question to be answered is whether the invention would have been obvious to the 'person skilled in the art'. Thus, the non-obviousness analysis is based on the distinction between the mental capabilities and knowledge of the notional person skilled in the art and the mental act of the inventor. However, with respect to AI-generated inventions the key output that has led to the invention is produced by AI. This is an important factor, because AI significantly expands the range of things that a human aided by AI can discover without undue effort or experiment, i.e. many inventions may be the result of a massive computational power that allows for rapid trial and error searching - something that an AI system can be programmed to do, while from a perspective of the person skilled in the art without the aid of AI the results may be surprising.[203] Therefore, without relevant changes in assessing this type of invention - human capabilities are essentially judged against AI capabilities. This sets a very low standard for obviousness that may render the majority of inventions generated by AI non-obvious to the person skilled in the art who relies only on their common general knowledge and mental capabilities.

This bring us to one of the key questions in the obviousness analysis of AI-generated inventions, which is how to define the person skilled in the art and whether/how the current standard should incorporate AI? Under the EPO Guidelines, the average person skilled in the art is presumed to have at their disposal 'the means and capacity for routine work and experimentation which are normal for the field of technology in question'.[204] The question is, therefore, has the use of a particular AI technology become a 'normal' tool for routine work in the relevant filed of technology?[205] If not, then, as was mentioned above, the use of an AI technology for the purpose of generating inventions may render all inventions non-obvious for the person skilled in the art without the assistance of an equivalent AI tool. How should this be addressed to avoid patent flooding? On the other hand, if the use of AI has become normal in the given field, what is the correct approach to construing the person skilled in the art for the purpose of AI-generated inventions, i.e., who should be the person skilled in the art or be included in the team of the persons skilled in the art?

Another crucial question relates to defining the relevant field of the invention and the scope of the prior art. Obviousness is assessed by 'hypothesising what would have been obvious at the priority date to the person skilled in the art to

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[203] Lisa Vertisky, 'Thinking Machines and Patent Law' in Barfield et al (eds.), Research Handbook on the Law of Artificial Intelligence (Edward Elgar, 2018) 497.

[204] EPO, Guidelines for Examination in the European Patent Office (November 2019) G-VII.3. See also Genentech's Patent [1989] R.P.C. 147 'the person skilled in the art should be credited with sufficient time and the best available equipment to carry out the work…'.

[205] Peter Blok, 'The Inventor's New Tool: Artificial Intelligence – How Does it Fit in the European Patent System?' (2017) EIPR 71.

which the patent in suit relates'[206] Therefore, the correct definition of the 'art' of the invention is the key element because it provides the basis for identifying the 'person skilled in the art' and their common general knowledge.[207] It is, therefore, important to establish the 'field of endeavour in which the inventors were working',[208] avoiding 'both unduly wide and unduly restrictive definitions' as this can create difficulties.[209] The properly defined relevant art further helps with the selection and assessment of the prior art.[210] In particular, when analysing obviousness, the courts narrow down a potentially very broad scope of the state of the art by assessing it through the eyes of the person skilled in the art, who is only expected to have scrutinised the information available in their own or closely related fields.[211]

For example, in Blue Gentian LLC v Tristar Products (UK) Ltd the invention concerned an expandable garden hose, while one of the prior art references, on which the obviousness attack was based, related to an oxygen hose used for air crew in an aircraft.[212] The court held that a garden water hose designer presented with the aircraft hose reference while reading it with interest, 'would also see a document which was not addressed to him or her'.[213] The court further stated that '[t]he teaching is concerned with something used in an environment and context a very long way from garden water hoses and subject to considerations which the garden water hose designer would know they knew little about.... They would not be confident the idea would be practical if applied to a garden water hose.'[214] Therefore, while the person skilled in the art may have access to a wide scope of the prior art, this may not 'translate into understanding or into the

[206] Technograph Printed Circuit Ltd v Mills & Rocky [1972] R.P.C. 346 at p. 362 (emphasis added). See also Paul G Cole and Richard Davis, CIPA Guide to the Patents Acts (Sweet & Maxwell, 8th edn, 2016) 172.

[207] ibid

[208] ibid

[209] ibid

[210] ibid

[211] Lionel Bently et al., Intellectual Property (5th edn, OUP 2018) 584.

[212] Blue Gentian LLC v Tristar Products (UK) Ltd [2013] EWHC 4098 (Pat).

[213]ibid

[214]ibid

integration of different technological fields'.[215] As one of the courts noted, 'knowing of a piece of prior art is one thing; appreciating its significance to the solution to the problem in hand is another'.[216] However, AI systems do not have similar restrictions as to specific fields of technology. On the contrary, the use of AI technologies may expand the scope of the prior art dramatically by their capability to delve into, learn and apply concepts from entirely unrelated fields. Therefore, an important question in this regard is what should be the ambit of the prior art for the purpose of the obviousness analysis of AI-generated inventions?

Finally, such notions as predictability and expectation of success currently play an important role in the assessment of obviousness. This is especially true with respect to the pharmaceutical and biotechnology industries, which are generally considered to be fraught with uncertainty.[217] It is, therefore, important to consider how the advances in AI technologies with significant processing capabilities affect uncertainty from a perspective of the person skilled in the art.[218] In other words, would such advancements in the AI technology make most inventions predictable and thus obvious to warrant patent protection under the current standards of patentability?

The issues raised above require urgent solutions. We believe that the current approach to the obviousness assessment must be adjusted by taking into account the advancements in AI technologies, and their role and impact on the inventive process. If the obviousness standard remains unchanged, this would establish a very low bar for patentability leading to an increasing number of patents, which, in turn, will exacerbate the problem of 'patent thickets' that is already significant in a number of industries.

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[215] Brenda M Simon, 'The Implications of Technological Advancement for Obviousness' (2013) 19 Mich. Telecomm. & Tech. L. Rev., 109.

[216] PLG Research [1994] FSR 116, 137.

[217] Clark Sullivan and Michael Kline, *Introduction to Patentability in Drug Development* (Future Science Ltd, 2016) 90 ('it is not possible to predict pharmaceutical activity ab initio').

[218] Brenda M Simon, 'The Implications of Technological Advancement for Obviousness' (2013) 19 Mich. Telecomm. & Tech. L. Rev., 105.

Considerations To Inform A Policy Response

fundamental objective of the patent system is to encourage the investment of human nancial resources and the taking of risk in generating inventions that may contribute positi the welfare of society. As such, the patent system is a fundamental component of innovat olicy more generally. Does the advent of inventions autonomously generated by AI applicati all for a re-assessment of the relevance of the patent incentive to AI-generated inventic pecifically,

) Should consideration be given to a sui generis system of IP rights for AI-generated inventi order to adjust innovation incentives for AI?

i) Is it too early to consider these questions because the impact of AI on both science chnology is still unfolding at a rapid rate and there is, at this stage, insufficient understandin at impact or of what policy measures, if any, might be appropriate in the circumstances?

Based on the above considerations, the answer to the key question of whether the outputs generated by AI technologies should be afforded patent protection depends on whether the provision of such protection corresponds to the rationale of the patent system itself, i.e. whether AI-generated inventions will be incentivised and rewarded through the grant of a patent.[219] When devising further policies in this area, it is also important to balance the interests of private parties with those of society. In particular, patenting of AI technologies coupled with 'big data' that trains such technologies and is owned by a small number of players on the market may significantly limit access to the process of innovation concentrating the returns from inventions in the hands of these players.[220] Such potential negative consequences should attract attention of patent and competition law policymakers in order to prevent restrictions on innovation and competition. It is also important to consider a broader perspective of a just

[219] Erica Fraser, 'Computers as Inventors Legal and Policy Implications of Artificial Intelligence on Patent Law' (2016) 13(3) Scripted 325.

[220] Lisa Vertisky, 'Thinking Machines and Patent Law' in Barfield et al (eds.), Research Handbook on the Law of Artificial Intelligence (Edward Elgar, 2018) 509.

distribution of benefits to all engaged in the inventive process in order to create the incentives 'to continue their investments of financial, physical and human capital'.[221] Finally, while the challenges posed by the present-day technology may be overcome and accommodated by the current patent law framework, a further sweeping development of AI technologies may require new approaches. Should the technology indeed reach the level of intellectual capability that is functionally equal to humans' capabilities (the 'strong AI'), then novel mechanisms to address the issues that will be raised by such a technology will be required, including new models for protecting the results generated by such an advanced technology.

Rights In Relation To Copyright

\n AI application can produce creative works by learning from data with AI tecl
nachine learning. The data used for training the AI application may represent crea
ıre subject to copyright (see also Issue 10). A number of issues arise in this regard,

Should the use of the data subsisting in copyright works without authorizatic
ning constitute an infringement of copyright? If not, should an explicit exception
yright law or other relevant laws for the use of such data to train AI applications?

(ii) If the use of the data subsisting in copyright works without authorizatic learning is considered to constitute an infringement of copyright, what would b the development of AI and on the free flow of data to improve innovation in A

(iii) If the use of the data subsisting in copyright works without authorizatic learning is considered to constitute an infringement of copyright, should an exc for at least certain acts for limited purposes, such as the use in non-commercial works or the use for research?

(iv) If the use of the data subsisting of copyright works without authorizatic learning is considered to constitute an infringement of copyright, how exceptions for text and data mining interact with such infringement?

[221]Ibid 507

(v) Would any policy intervention be necessary to facilitate licensing if the unauthorized u data subsisting in copyright works for machine learning were to be considered an infringe of copyright?

(vi) How would the unauthorized use of data subsisting in copyright works for mac learning be detected and enforced, in particular when a large number of copyright work created by AI?

(v) Should the use of the data subsisting in copyright works without authorization for machine learning constitute an infringement of copyright? If not, should an explicit exception be made under copyright law or other relevant laws for the use of such data to train AI applications?

The discussion on whether AI should be considered to infringe economic rights, for example, would benefit from an investigation on how the infringement of different rights is assessed in relation to each specific work or subject-matter, and whether economic rights are engaged at all, in light of specific AI deployments[222] Another important consideration would be whether it would ever be possible for AI systems to be "taught" copyright law and be trained not to infringe, particularly in view of complex copyright principles such as the idea-expression dichotomy,[223] the possibility of non-literal copying constituting infringement of certain works, tests that operate on a qualitative instead of quantitative basis, different periods of protection for different subject-matters etc. It is also suggested that consideration of moral rights should also be expressly referred to in the question.[224]

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[222] For example, is the AI reproducing an original part, or merely copying a style? In this respect, Esposti et al explain that "the concept of "style" itself is a very ambiguous and questionable one, vaguely defined and also strongly dependent on the medium (written text, visual art, video, music, etc)": Mirko Degli Esposti, Francesca Lagioia and Giovanni Sartor, "The Use of Copyrighted Works by AI Systems: Art Works in the Data Mill" (2019) European Journal of Risk Regulation 8.

[223] TRIPS, art 9(2).

[224] E.g., Berne Convention, art 6 bis, WIPO Performances and Phonograms Treaty 1996 (WPPT), art 5.

On limitations and exceptions, it is important to address the question on whether new limitations and exceptions should be created, both in the context of innovative AI usages, but also in the context of already existing sector-specific discussions: for example, the need to facilitate the creation of or access to datasets for the AI to "learn" from can be addressed in the context of discussions on limitations and exceptions to allow digitization of libraries and archives.[225] However, it is also extremely important to address the extent to which existing limitations and exceptions may already be used in the context of specific AI deployments, such as the quotation exception in article 10(1) of the Berne Convention.[226]

It is suggested, therefore, that the following two separate general issues, and their specific sub-issues, are addressed in depth, in relation to specific deployments of AI: (1) the extent to which exclusive rights are possibly being infringed (e.g. reproduction, adaptation, communication to the public etc.) and in relation to which subject-matter; and (2) the extent to which existing limitations and exceptions are already applicable, and whether and how should new limitations and exceptions be created (exceptions to which rights, and under which conditions, e.g. the three-step test).[227]

[225] As per the WIPO website: "Limitations and exceptions is an issue considered in the agenda of the WIPO Standing Committee for Copyright and Related Rights (SCCR) and, recently, its debate has been focused mainly on three groups of beneficiaries or activities in relation to exceptions and limitations – on educational activities, on libraries and archives and on disabled persons, particularly visually impaired persons." <https://www.wipo.int/copyright/en/limitations/> accessed 14 February 2020.
[226] An exception which Bently and Aplin have recently dubbed "global, mandatory, fair use": Lionel Bently and Tanya Aplin, "Whatever Became of Global, Mandatory, Fair Use? A Case Study in Dysfunctional Pluralism" in Susy Frankel (ed), Is Intellectual Property Pluralism Functional? (Edward Elgar, 2019).
[227]Berne Convention, art 9(2), TRIPS Agreement, art 13.

CHAPTER NINE

Case Studies in AI

Copy Right And Ai

Burrow Gilles Lithographic Co. v. Sarony

This case revolved around whether a copyright protection can be granted to a photograph.[228] It was a relevant case because it addressed the dichotomy between creative and mechanical labour. The Court discussed the possibility of granting copyright protection to a product which is the output of a machine. The Court, by holding that purely mechanical labour is per se not creative, narrowed the scope of their protection. Therefore, if a strict approach like this were to be applied to AI systems, granting copyright for works created by them, would be difficult.

Bleistein v. Donaldson Lithographing Co.

This case was a continuation of the question of law considered in the previous case. The Court herein clearly differentiated between a human's work and something artificial. Justice Holmes, writing for the majority, delineated the uniqueness of human personality and stipulated the same as a prerequisite to a copyright.[229] The Court made its stance clear by using the words 'something irreducible, which is one man's alone' which meant that there was no scope for anything that was not a product of man's creativity.[230]

Alfred Bell & Co. v. Catalda Fine Arts, Inc.

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[228] Burrow Gilles Lithographic v. Sarony, 111 U.S. 53 (1884).
[229] Bleistein v. Donaldson Lithographing Co., 188 U.S. 239 (1903).
[230]Ibid

[This judgment witnessed a softer approach towards copyrights being adopted by [t]he Courts. The Court lowered the standard for originality and held that the [w]ork to be original, it must not be copied from any other artistic work of similar [c]haracter.[231] It even held that unintentional or accidental variations may be [c]laimed by an author as his or her own. This judgment therefore was a respite to [p]eople claiming copyrights for work generated by AIs as it wasn't copied, despite [i]t being generated through certain programming and algorithms. These three [j]udgments, to some extent, clear the ambiguity that prevails around grant of [p]rotection to AI systems. However, a lack of definitive stance still affects the [p]rospective right holders.

[T]He Way Forward

[T]here is no denying that AI is bound to develop increasingly by each passing day. [W]ith companies like GE, IBM, Apple, etc., advancing their attempts toward [r]evolutionizing technologies related to providing software solutions, [s]ophisticated technologies based on AI are bound to increase the number of such [']inventions' which may come about. There exists immense scope for legislators [t]o develop guidelines in determining of such situations, providing it the most [a]dequate form of legal safeguarding. However, the author shares the view of [S]tephen Hawking when he states that the autonomy of AI can diminish the [w]orth of human thinking and invention. A more favourable solution would be [t]o grant a more collaborative form of patent protection for the inventions made [b]y an AI. This is because a human element is essential in managing the rights and [o]bligations associated with patents, which cannot be done solely with a machine. [F]urther, with increasing prospects of using thousands of AI enabled networks [w]hich function with or without human intervention, patent protection requires [t]o be awarded on some anthropomorphic agent, who may be recognized in case [s]uch invention malfunctions, or causes a possible violation of law, therefore [a]ttracting criminal liability. It must be remembered that in the quest of making [I]P laws adaptable to the changing technologies, one cannot choose to create an [i]mbalance by diminishing the desired effects of criminal laws, which necessarily

[231] Alfred Bell & Co. V. Catalda Fine Arts, Inc.,191 F.2d 99 (2d Cir. 1951).

urvive on human elements being involved. Additionally, we cannot completely ubmit to AI technologies, which would possibly reduce the role of the human ace itself.

A Uniform Recognition for AIs.

Despite AIs being a reality around the world, they only carry recognition in a select few countries like United States, England and New Zealand. A positive step towards the recognition of AIs could be that, all member countries of multilateral trading forums begin to recognize the same, for instance, in the form of an amendment to TRIPS.

Automatic Identification System

The **automatic identification system** (**AIS**) is an automatic tracking system that uses transceivers on ships and is used by vessel traffic services (VTS). When satellites are used to receive AIS signatures, the term Satellite-AIS (S-AIS) is used. AIS information supplements marine radar, which continues to be the primary method of collision avoidance for water transport. Although technically and operationally distinct, the ADS-B system is analogous to AIS and performs a similar function for aircraft.

Information provided by AIS equipment, such as unique identification, position, course, and speed, can be displayed on a screen or an electronic chart display and information system (ECDIS). AIS is intended to assist a vessel's watch standing officers and allow maritime authorities to track and monitor vessel movements. AIS integrates a standardized VHF transceiver with a positioning system such as a Global Positioning System receiver, with other electronic navigation sensors, such as a gyrocompass or rate of turn indicator. Vessels fitted with AIS transceivers can be tracked by AIS base stations located along coast lines or, when out of range of terrestrial networks, through a growing number of satellites that are fitted with special AIS receivers which are capable of deconflicting a large number of signatures.

The International Maritime Organization's International Convention for the Safety of Life at Sea requires AIS to be fitted aboard international voyaging ships with 300 or more gross tonnage (GT), and all passenger ships regardless of size.[232] For a variety of reasons, ships can turn off their AIS transceivers.[233]

Viewing And Using Ais Data

AIS is intended, primarily, to allow ships to view marine traffic in their area and to be seen by that traffic. This requires a dedicated VHF AIS transceiver that allows local traffic to be viewed on an AIS enabled chart plotter or computer monitor while transmitting information about the ship itself to other AIS receivers. Port authorities or other shore-based facilities may be equipped with receivers only, so that they can view the local traffic without the need to transmit their own location. All AIS transceivers equipped traffic can be viewed this way very reliably but is limited to the VHF range, about 10–20 nautical miles.

If a suitable chart plotter is not available, local area AIS transceiver signals may be viewed via a computer using one of several computer applications such as Ship Plotter, Gnuais or Open CPN. These demodulate the signal from a modified marine VHF radiotelephone tuned to the AIS frequencies and convert into a digital format that the computer can read and display on a monitor; this data may then be shared via a local or wide area network via TCP or UDP protocols but will still be limited to the collective range of the radio receivers used in the network.[234]Because computer AIS monitoring applications and normal VHF radio transceivers do not possess AIS transceivers, they may be used by shore-based facilities that have no need to transmit or as an inexpensive alternative to a dedicated

[232] http://en.wikepedia.org/wiki/Automatic identification system# cite note 1
[233] http://en.wikepedia.org/wiki/Automatic identification system# cite note 2
[234] http://en.wikepedia.org/wiki/Automatic identification system# cite note 3

AIS device for smaller vessels to view local traffic but, of course, the user will remain unseen by other traffic on the network.

A secondary, unplanned and emerging use for AIS data is to make it viewable publicly, on the internet, without the need for an AIS receiver. Global AIS transceiver data collected from both satellite and internet-connected shore-based stations are aggregated and made available on the internet through a number of service providers. Data aggregated this way can be viewed on any internet-capable device to provide near global, real-time position data from anywhere in the world. Typical data includes vessel name, details, location, speed and heading on a map, is searchable, has potentially unlimited, global range and the history is archived. Most of this data is free of charge but satellite data and special services such as searching the archives are usually supplied at a cost. The data is a read-only view and the users will not be seen on the AIS network itself. Shore-based AIS receivers contributing to the internet are mostly run by a large number of volunteers.[235] AIS mobile apps are also readily available for use with Android, Windows and iOS devices. See External links below for a list of internet-based AIS service providers. Ship owners and cargo dispatchers use these services to find and track vessels and their cargoes while marine enthusiasts may add to their photograph collections.

Deployment History

At the simplest level, AIS operates between pairs of radio transceivers, one of which is always on a vessel. The other may be on a vessel, on-shore (terrestrial), or on a satellite. Respectively, these represent ship to ship, ship to shore, and ship to satellite operation and follow in that order.

Vessel-Based AIS Transceivers

The 2002 IMO SOLAS Agreement included a mandate that required most vessels over 300GT on international voyages to fit a Class A type AIS transceiver. This was

[235] http://en.wikepedia.org/wiki/Automatic identification system# cite note 2

the first mandate for the use of AIS equipment and affected approximately 100,000 vessels.

In 2006, the AIS standards committee published the Class B type AIS transceiver specification, designed to enable a simpler and lower-cost AIS device. Low-cost Class B transceivers became available in the same year triggering mandate adoptions by numerous countries and making large-scale installation of AIS devices on vessels of all sizes commercially viable.

Since 2006, the AIS technical standard committees have continued to evolve the AIS standard and product types to cover a wide range of applications from the largest vessel to small fishing vessels and life boats. In parallel, governments and authorities have instigated projects to fit varying classes of vessels with an AIS device to improve safety and security. Most mandates are focused on commercial vessels, with leisure vessels selectively choosing to fit. In 2010 most commercial vessels operating on the European Inland Waterways were required to fit an Inland waterway certified Class A, all EU fishing boats over 15m must have a Class A by May 2014,[236] and the US has a long-pending extension to their existing AIS fit rules which is expected to come into force during 2013. It is estimated that as of 2012, some 250,000 vessels have fitted an AIS transceiver of some type, with a further 1 million required to do so in the near future and even larger projects under consideration.

Terrestrial-based AIS (T-AIS)

AIS was developed in the 1990s as a high intensity, short-range identification and tracking network. Shipboard and land-based AIS transceivers have a horizontal range that is highly variable, but typically only up to about 74 kilometres (46 mi). Approximate line-of-sight propagation limitations mean that terrestrial AIS (T-AIS) is lost beyond coastal waters. [237] In addition to port and maritime authority operated transceivers, there is large network of privately owned ones as well.

[236] http://en.wikepedia.org/wiki/Automatic identification system# cite note 6
[237] http://en.wikepedia.org/wiki/Automatic identification system# cite note 7

Satellite-Based AIS (S-AIS)

In the 1990s AIS was not anticipated to be detectable from space. Nevertheless, since 2005, various entities have been experimenting with detecting AIS transmissions using satellite-based receivers and, since 2008, companies such as exact Earth, ORBCOMM, Space quest, Spire and also government programs have deployed AIS receivers on satellites. The time-division multiple access (TDMA) radio access scheme used by the AIS system creates significant technical issues for the reliable reception of AIS messages from all types of transceivers: Class A, Class B, Identifier, A to N and SART. However, the industry is seeking to address these issues through the development of new technologies and over the coming years the current restriction of satellite AIS systems to Class A messages is likely to dramatically improve with the addition of Class B and Identifier messages.

The fundamental challenge for AIS satellite operators is the ability to receive very large numbers of AIS messages simultaneously from a satellite's large reception footprint. There is an inherent issue within the AIS standard; the TDMA radio access scheme defined in the AIS standard creates 4,500 available time-slots in each minute but this can be easily overwhelmed by the large satellite reception footprints and the increasing numbers of AIS transceivers, resulting in message collisions, which the satellite receiver cannot process. Companies such as exact Earth are developing new technologies such as ABSEA, that will be embedded within terrestrial and satellite-based transceivers, which will assist the reliable detection of Class B messages from space without affecting the performance of terrestrial AIS.

The addition of satellite-based Class A and B messages could enable truly global AIS coverage but, because the satellite-based TDMA limitations will never match the reception performance of the terrestrial-based network, satellites will augment rather than replace the terrestrial system.

AIS has much longer vertical (than horizontal) transmission – up to the 400 km orbit of the International Space Station (ISS).

NASA video demonstrating the advantages of the Norwegian AIS satellite program, illustrated by the AIS transceiver on board the International Space Station.

In November 2009, the STS-129 space shuttle mission attached two antennas—an AIS VHF antenna, and an Amateur Radio antenna—to the Columbus module of the ISS. Both antennas were built in cooperation between ESA and the ARISS team (Amateur Radio on ISS). Starting from May 2010 the European Space Agency is testing an AIS receiver from Kongsberg Seatex (Norway) in a consortium led by the Norwegian Defence Research Establishment in the frame of technology demonstration for space-based ship monitoring. This is a first step towards a satellite-based AIS-monitoring service.[238]

In 2009, ORBCOMM launched AIS enabled satellites in conjunction with a US Coast Guard contract to demonstrate the ability to collect AIS messages from space. In 2009, Luxspace, a Luxembourg-based company, launched the RUBIN-9.1 satellite (AIS Pathfinder 2). The satellite is operated in cooperation with SES and REDU Space Services.[239]In late 2011 and early 2012, ORBCOMM and Luxspace launched the Vessels at AIS microsatellites, one in an equatorial orbit and the other in a polar orbit (VesselSat-2 and VesselSat-1).

In 2007, the U.S. tested space-based AIS tracking with the TacSat-2 satellite. However, the received signals were corrupted because of the simultaneous receipt of many signals from the satellite footprint.[240]

In July 2009, Space Quest launched AprizeSat-3 and AprizeSat-4 with AIS receivers.[241] These receivers were successfully able to receive the U.S. Coast Guard's SART test beacons off of Hawaii in 2010.In July 2010, Space Quest and exact Earth of Canada announced an arrangement whereby data from AprizeSat-3 and

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[238] http://en.wikepedia.org/wiki/Automatic identification system# cite note 8

[239] http://en.wikepedia.org/wiki/Automatic identification system# cite note 9

[240] http://en.wikepedia.org/wiki/Automatic identification system# cite note 10

[241] http://en.wikepedia.org/wiki/Automatic identification system# cite note 11

AprizeSat-4 would be incorporated into the exact Earth system and made available worldwide as part of their exact AIS (TM)service.

On July 12, 2010, the Norwegian AISSat-1 satellite was successfully launched into polar orbit. The purpose of the satellite is to improve surveillance of maritime activities in the High North. AISSat-1 is a nano-satellite, measuring only 20×20×20 cm, with an AIS receiver made by Kongsberg Seatex. It weighs 6 kilograms and is shaped like a cube.[242]

On 20 April 2011, Indian Space Research Organisation launched Resourcesat-2 containing a S-AIS payload for monitoring maritime traffic in the Indian Ocean Search & Rescue (SAR) zone. AIS data is processed at National Remote Sensing Centre and archived at Indian Space Science Data Centre.

On February 25, 2013 after one year launch delay Aalborg University launched AAUSAT3. It is a 1U cubes at, weights 800 grams, solely developed by students from the Department of Electronic Systems. It carries two AIS receivers a traditional and a SDR-based receiver. The project was proposed and sponsored by the Danish Maritime Safety Administration. It has been a huge success and has in the first 100 days downloaded more than 800,000 AIS messages and several 1 MHz raw samples of radio signals. It receives both AIS channels simultaneously and has received class A as well as class B messages. Cost including launch was less than €200,000.

Canadian-based exact Earth's AIS satellite network provides global coverage using 8 satellites. Between January 2017 and January 2019, this network was significantly expanded through a partnership with L3Harris Corporation with 58 hosted payloads on the Iridium NEXT constellation.[243] Additionally exact Earth is involved in the development of ABSEA technology which will enable its network to reliably detect a high proportion of Class B type messages, as well as Class A.

ORBCOMM operates a global satellite network that includes 18 AIS-enabled satellites. ORBCOMM's OG2 (ORBCOMM Generation 2) satellites are equipped

[242] http://en.wikepedia.org/wiki/Automatic identification system# cite note 13

[243] http://en.wikepedia.org/wiki/Automatic identification system# cite note 15

with an Automatic Identification System (AIS) payload to receive and report transmissions from AIS-equipped vessels for ship tracking and other maritime navigational and safety efforts, and download at ORBCOMM's sixteen existing earth stations around the globe.

In July 2014, ORBCOMM launched the first 6 OG2 satellites aboard a SpaceX Falcon 9 rocket from Cape Canaveral, Florida. Each OG2 satellite carries an AIS receiver payload. All 6 OG2 satellites were successfully deployed into orbit and started sending telemetry to ORBCOMM soon after launch. In December 2015, the company launched 11 additional AIS-enabled OG2 satellites aboard the SpaceX Falcon 9 rocket. This dedicated launch marked ORBCOMM's second and final OG2 mission to complete its next-generation satellite constellation. Compared to its current OG1 satellites, ORBCOMM's OG2 satellites are designed for faster message delivery, larger message sizes and better coverage at higher latitudes, while increasing network capacity.

In August 2017, Spire Global Inc. released an API that delivers S-AIS data enhanced with machine learning (Vessels and Predict) backed by its 40+ constellation of nano-satellites.[17]

Correlation of data sources

Correlating optical and radar imagery with S-AIS signatures enables the end-user to rapidly identify all types of vessels. A great strength of S-AIS is the ease with which it can be correlated with additional information from other sources such as radar, optical, ESM, and more SAR related tools such as GMDSS SARSAT and AMVER. Satellite-based radar and other sources can contribute to maritime surveillance by detecting all vessels in specific maritime areas of interest, a particularly useful attribute when trying to co-ordinate a long-range rescue effort or when dealing with VTS issues

Applications

A vessel's text-only AIS display, listing nearby vessels' range, bearings, and names, The original purpose of AIS was solely collision avoidance but many other applications have since developed and continue to be developed. AIS is currently used for:

Collision avoidance

AIS was developed by the IMO technical committees as a technology to avoid collisions among large vessels at sea that are not within range of shore-based systems. The technology identifies every vessel individually, along with its specific position and movements, enabling a virtual picture to be created in real time. The AIS standards include a variety of automatic calculations based on these position reports such as Closest Point of Approach (CPA) and collision alarms. As AIS is not used by all vessels, AIS is usually used in conjunction with radar. When a ship is navigating at sea, information about the movement and identity of other ships in the vicinity is critical for navigators to make decisions to avoid collision with other ships and dangers (shoal or rocks). Visual observation (e.g., unaided, binoculars, and night vision), audio exchanges (e.g., whistle, horns, and VHF radio), and radar or automatic radar plotting aid are historically used for this purpose. These preventive mechanisms sometimes fail due to time delays, radar limitations, miscalculations, and display malfunctions, and can result in a collision. While requirements of AIS are to display only very basic text information, the data obtained can be integrated with a graphical electronic chart or a radar display, providing consolidated navigational information on a single display.

Fishing fleet monitoring and control

AIS is widely used by national authorities to track and monitor the activities of their national fishing fleets. AIS enables authorities to reliably and cost effectively monitor fishing vessel activities along their coast line, typically out to a range of 100 km (60 mi), depending on location and quality of coast-based receivers/base stations with supplementary data from satellite-based networks.

Maritime security

AIS enables authorities to identify specific vessels and their activity within or near a nation's Exclusive Economic Zone. When AIS data is fused with existing radar systems, authorities are able to differentiate between vessels more easily. AIS data can be automatically processed to create normalized activity patterns for individual vessels, which when breached, create an alert, thus highlighting potential threats for more efficient use of security assets. AIS improves maritime domain awareness and allows for heightened security and control. Additionally, AIS can be applied to freshwater river systems and lakes.

Aids to navigation

The AIS aids to navigation (A to N) product standard was developed with the ability to broadcast the positions and names of objects other than vessels, such as navigational aid and marker positions and dynamic data reflecting the marker's environment (e.g., currents and climatic conditions). These aids can be located on shore, such as in a lighthouse, or on water, platforms, or buoys. The U.S. Coast Guard has suggested that AIS might replace racon (radar beacons) currently used for electronic navigation aids.[244]A to Ns enable authorities to remotely monitor the status of a buoy, such as the status of the lantern, as well as transmit live data from sensors (such as weather and sea state) located on the buoy back to vessels fitted with AIS transceivers or local authorities. An A to N will broadcast its position and Identity along with all the other information. The A to N standard also permits the transmit of 'Virtual A to N' positions whereby a single device may transmit messages with a 'false' position such that an A to N marker appears on electronic charts, although a physical A to N may not be present at that location.

Search and rescue

For coordinating on-scene resources of a marine search and rescue (SAR) operation, it is imperative to have data on the position and navigation status of other ships in the vicinity. In such cases, AIS can provide additional information and enhance awareness of available resources, even if the AIS range is limited to VHF radio range. The AIS standard also envisioned the possible use on SAR aircraft, and included a message (AIS Message 9) for aircraft to report their position. To aid SAR vessels and aircraft in locating people in distress, the specification (IEC 61097-14 Ed 1.0) for an AIS-based SAR transmitter (AIS-SART) was developed by

[244] httpp//en.wikiprdia.org/wiki//Automatii identification system#cite note-18

the IEC's TC80 AIS work group. AIS-SART was added to Global Maritime Distress Safety System regulations effective January 1, 2010.AIS-SARTs have been available on the market since at least 2009.Recent regulations have mandated the installation of AIS systems on all Safety Of Life At Sea (SOLAS) vessels and vessels over 300 tons.[245]

Accident investigation

AIS information received by VTS is important for accident investigation since it provides accurate historical data on time, identity, GPS-based position, compass heading, course over ground, speed (by log/SOG), and rates of turn, rather than the less accurate information provided by radar. A more complete picture of the events could be obtained by Voyage Data Recorder (VDR) data if available and maintained on board for details of the movement of the ship, voice communication and radar pictures during the accidents. However, VDR data are not maintained due to the limited twelve hours storage by IMO requirement.

Ocean currents estimates

Ocean surface current estimates based on the analysis of AIS data have been available from French company, e-Odyn, since December 2015.

Infrastructure protection

AIS information can be used by owners of marine seabed infrastructure, such as cables or pipelines, to monitor the activities of vessels close to their assets in close to real time. This information can then be used to trigger alerts to inform the owner and potentially avoid an incident where damage to the asset might occur.

Fleet and cargo tracking

[245] http://en.wikepedia.org/wiki/Automatic identification system# cite note 21

Internet disseminated AIS can be used by fleet or ship managers to keep track of the global location of their ships. Cargo dispatchers, or the owners of goods in transit can track the progress of cargo and anticipate arrival times in port.

The AIS standard comprises several sub standards called "types" that specify individual product types. The specification for each product type provides a detailed technical specification which ensures the overall integrity of the global AIS system within which all the product types must operate. The major product types described in the AIS system standards are:

Class A

Vessel-mounted AIS transceiver which operates using SOTDMA. Targeted at large commercial vessels, SOTDMA requires a transceiver to maintain a constantly updated slot map in its memory such that it has prior knowledge of slots which are available for it to transmit. SOTDMA transceivers will then pre-announce their transmission, effectively reserving their transmit slot. SOTDMA transmissions are therefore prioritised within the AIS system. This is achieved through 2 receivers in continuous operation. Class A's must have an integrated display, transmit at 12.5 W, interface capability with multiple ship systems, and offer a sophisticated selection of features and functions. Default transmit rate is every few seconds. AIS Class A type compliant devices receive all types of AIS messages.

Class B

There are now two separate IMO specifications for Class B transceivers (aimed at lighter commercial and leisure markets): a carrier-sense time-division multiple-access (CSTDMA) system, and a system that uses SOTDMA (as in Class A).

In the original CSTDMA-based system, defined in ITU M.1371-0 and now called Class B "CS" (or unofficially as Class B/CS),[246] transceivers listen to the slot map immediately prior to transmitting and seek a slot where the 'noise' in the slot is the same (or similar) to background noise, thereby indicating that the slot is not being used by another AIS device. Class B "CS" transmits at 2 W and is not required to

[246246] httpp//en.wikiprdia.org/wiki//Automatii identification system cite note-dyacht201811-27

have an integrated display: Class B "CS" units can be connected to most display systems where the received messages will be displayed in lists or overlaid on charts. Default transmit rate is normally every thirty seconds, but this can be varied according to vessel speed or instructions from base stations. The Class B "CS" standard requires integrated GPS and certain LED indicators. Class B "CS" equipment receives all types of AIS messages.

The newer SOTDMA Class B "SO" system, [sometimes referred to as Class B/SO or Class B+, [247] leverages the same time slot finding algorithm as Class A, and has the same transmission priority as Class A transmitters, helping to guarantee that it will always be able to transmit. The Class B "SO" technology will also change its rate of transmission depending on the speed the vessel is going, up to every five seconds over 23 knots, instead of the constant rate of every thirty seconds in Class B "CS". Finally, Class B "SO" will also broadcast at a power of 5 W instead of t[248]he previous 2 W of Class B "CS".[249]

Base station

Shore-based AIS transceiver (transmit and receive) which operates using SOTDMA. Base stations have a complex set of features and functions which in the AIS standard are able to control the AIS system and all devices operating therein. Ability to interrogate individual transceivers for status reports and or transmit frequency changes.

Aids to navigation (A to N)

Shore- or buoy-based transceiver (transmit and receive) which operates using fixed-access time-division multiple-access (FATDMA). Designed to collect and transmit data related to sea and weather conditions as well as relay AIS messages to extend network coverage.

Search and rescue transceiver (SART)

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[247] httpp//en.wikiprdia.org/wiki//Automatii identification system cite note-dyacht201811-27
[248]

[249] httpp//en.wikiprdia.org/wiki//Automatii identification system cite note-dyacht201811-27

Specialist AIS device created as an emergency distress beacon which operates using pre-announce time-division multiple-access (PATDMA), or sometimes called a "modified SOTDMA". The device randomly selects a slot to transmit and will transmit a burst of eight messages per minute to maximize the probability of successful transmission. A SART is required to transmit up to a maximum of five miles and transmits a special message format recognised by other AIS devices. The device is designed for periodic use and only in emergencies due to its PATDMA-type operation which places stress on the slot map.

Specialist AIS transceivers

Despite there being IMO/IEC published AIS specifications, a number of authorities have permitted and encouraged the development of hybrid AIS devices. These devices seek to maintain the integrity of the core AIS transmission structure and design to ensure operational reliability, but to add a range of additional features and functions to suit their specific requirements. The "Identifier" AIS transceiver is one such product where the core Class B CSTDMA technology is designed to ensure that the device transmits in complete compliance with the IMO specifications, but a number of changes have been made to enable it to be battery powered, low cost and easier to install and deploy in large numbers. Such devices will not have international certification against an IMO specification since they will comply with a proportion of the relevant specification. Typically, authorities will make their own detailed technical evaluation and test to ensure that the core operation of the device does not harm the international AIS system.

AIS receivers are not specified in the AIS standards, because they do not transmit. The main threat to the integrity of any AIS system are non-compliant AIS transmissions, hence careful specifications of all transmitting AIS devices. However, it is well to note that AIS transceivers all transmit on multiple channels as required by the AIS standards. As such single-channel, or multiplexed, receivers will not receive all AIS messages. Only dual-channel receivers will receive all AIS messages.

Type testing and approval

AIS is a technology which has been developed under the auspices of the IMO by its technical committees. The technical committees have developed and published a series of AIS product specifications. Each specification defines a specific AIS product which has been carefully created to work in a precise way with all the other defined AIS devices, thus ensuring AIS system interoperability worldwide. Maintenance of the specification integrity is deemed critical for the performance of the AIS system and the safety of vessels and authorities using the technology. As such most countries require that AIS products are independently tested and certified to comply with a specific published specification. Products that have not been tested and certified by a competent authority, may not conform to the required AIS published specification and therefore may not operate as expected in the field. The most widely recognized and accepted certifications are the R&TTE Directive, the U.S. Federal Communications Commission, and Industry Canada, all of which require independent verification by a qualified and independent testing agency.

Message types

There are 27 different types of top-level messages defined in ITU M.1371-5 (out of a possibility of 64) that can be sent by AIS transceivers.

AIS messages 6, 8, 25, and 26 provide "Application Specific Messages" (ASM), that allow "competent authorities" to define additional AIS message subtypes. There are both "addressed" (ABM) and "broadcast" (BBM) variants of the message. Addressed messages, while containing a destination MMSI, are not private and may be decoded by any receiver.

One of the first uses of ASMs was the Saint Lawrence Seaway use of AIS binary messages (message type 8) to provide information about water levels, lock orders, and weather. The Panama Canal uses AIS type 8 messages to provide information about rain along the canal and wind in the locks. In 2010, the International Maritime Organization issued Circular 289 that defines the next iteration of ASMs for type 6 and 8 messages. Alexander, Schwehr and Zetterberg proposed that the community of competent authorities work together to maintain a regional register of these messages and their locations of use. The International Association of

Marine Aids to Navigation and Lighthouse Authorities (IALA-AISM) now established a process for collection of regional application-specific messages.

Detailed description

Each AIS transceiver consists of one VHF transmitter, two VHF TDMA receivers, one VHF Digital Selective Calling (DSC) receiver, and links to shipboard display and sensor systems via standard marine electronic communications (such as NMEA 0183, also known as IEC 61162). Timing is vital to the proper synchronization and slot mapping (transmission scheduling) for a Class A unit. Therefore, every unit is required to have an internal time base, synchronized to a global navigation satellite system (e.g. GPS) receiver. This internal receiver may also be used for position information. However, position is typically provided by an external receiver such as GPS, LORAN-C or an inertial navigation system and the internal receiver is only used as a backup for position information. Other information broadcast by the AIS, if available, is electronically obtained from shipboard equipment through standard marine data connections. Heading information, position (latitude and longitude), "speed over ground", and rate of turn are normally provided by all ships equipped with AIS. Other information, such as destination, and ETA may also be provided.

An AIS transceiver normally works in an autonomous and continuous mode, regardless of whether it is operating in the open seas or coastal or inland areas. AIS transceivers use two different frequencies, VHF maritime channels 87B (161.975 MHz) and 88B (162.025 MHz), and use 9.6 kbit/s Gaussian minimum shift keying (GMSK) modulation over 25 kHz channels using the high-level data link control (HDLC) packet protocol. Although only one radio channel is necessary, each station transmits and receives over two radio channels to avoid interference problems, and to allow channels to be shifted without communications loss from other ships. The system provides for automatic contention resolution between itself and other stations, and communications integrity is maintained even in overload situations.

In order to ensure that the VHF transmissions of different transceivers do not occur at the same time, the signals are time multiplexed using a technology called self-organized time-division multiple access (SOTDMA). The design of this technology is patented,[37] and whether this patent has been waived for use by SOLAS vessels is a matter of debate between the manufacturers of AIS systems and the patent holder, Håkan Lans. Moreover, the United States Patent and Trademark Office (USPTO) cancelled all claims in the original patent on March 30, 2010.[38]

In order to make the most efficient use of the bandwidth available, vessels that are anchored or moving slowly transmit less frequently than those that are moving faster or are maneuvering. The update rate ranges from 3 minutes for anchored or moored vessels, to 2 seconds for fast moving or maneuvering vessels, the latter being similar to that of conventional marine radar.

Each AIS station determines its own transmission schedule (slot), based upon data link traffic history and an awareness of probable future actions by other stations. A position report from one station fits into one of 2,250 time slots established every 60 seconds on each frequency. AIS stations continuously synchronize themselves to each other, to avoid overlap of slot transmissions. Slot selection by an AIS station is randomized within a defined interval and tagged with a random timeout of between 4 and 8 minutes. When a station changes its slot assignment, it announces both the new location and the timeout for that location. In this way new stations, including those stations which suddenly come within radio range close to other vessels, will always be received by those vessels.

The required ship reporting capacity according to the IMO performance standard is a minimum of 2,000 time slots per minute, though the system provides 4,500 time slots per minute. The SOTDMA broadcast mode allows the system to be overloaded by 400 to 500% through sharing of slots, and still provides nearly 100% throughput for ships closer than 8 to 10 nmi to each other in a ship-to-ship mode. In the event of system overload, only targets further away will be subject to drop-out, in order to give preference to nearer targets, which are of greater concern to ship operators. In practice, the capacity of the system is nearly unlimited, allowing for a great number of ships to be accommodated at the same time.

The system coverage range is similar to other VHF applications. The range of any VHF radio is determined by multiple factors, the primary factors are: the height and quality of the transmitting antenna and the height and quality of the receiving antenna. Its propagation is better than that of radar, due to the longer wavelength, so it is possible to reach around bends and behind islands if the land masses are not too high. The look-ahead distance at sea is nominally 20 nmi (37 km). With the help of repeater stations, the coverage for both ship and VTS stations can be improved considerably.

The system is backward compatible with digital selective calling systems, allowing shore-based GMDSS systems to inexpensively establish AIS operating channels and identify and track AIS-equipped vessels, and is intended to fully replace existing DSC-based transceiver system

Shore-based AIS network systems are now being built up around the world. One of the biggest fully operational, real-time systems with full routing capability is in China. This system was built between 2003 and 2007 and was delivered by Saab Transpondere Tech the entire Chinese coastline is covered with approximately 250 base stations in hot-standby configurations including 70 computer servers in three main regions. Hundreds of shore-based users, including about 25 vessel traffic service (VTS) canters, are connected to the network and are able to see the maritime picture, and can also communicate with each ship using SRMs (Safety Related Messages). All data are in real time. The system was designed to improve the safety and security of ships and port facilities. It is also designed according to an SOA architecture with socket-based connection and using IEC AIS standardized protocol all the way to the VTS users. The base stations have hot-standby units (IEC 62320-1) and the network is the third-generation network solution.

By the beginning of 2007, a new worldwide standard for AIS base stations was approved, the IEC 62320-1 standard. The old IALA recommendation and the new IEC 62320-1 standard are in some functions incompatible, and therefore attached network solutions have to be upgraded. This will not affect users, but system builders need to upgrade software to accommodate the new standard. A standard for AIS base stations has been long-awaited. Currently ad-hoc networks exist with class A mobiles. Base stations can control the AIS message traffic in a region, which will hopefully reduce the number of packet collisions.

Broadcast information.

An AIS transceiver sends the following data every 2 to 10 seconds depending on a vessel's speed while underway, and every 3 minutes while a vessel is at anchor:

Vessel Maritime Mobile Service Identity (MMSI): a unique nine-digit identification number.

Navigation status: E.g., "at anchor", "under way using engine(s)", "not under command", etc.

Rate of turn: right or left, from 0 to 720 degrees per minute

Speed over ground: 0.1-knot (0.19 km/h) resolution from 0 to 102 knots (189 km/h)

Positional resolution:

Longitude: to 0.0001 arcminutes

Latitude: to 0.0001 arcminutes

Course over ground: relative to true north to 0.1°

True heading: 0 to 359° (for example from a gyro compass)

True bearing at own position: 0 to 359°

UTC seconds: The seconds field of the UTC time when these data were generated. A complete timestamp is not present.

In addition, the following data are broadcast every 6 minutes:

IMO ship identification number: a seven-digit number that remains unchanged upon transfer of the ship's registration to another country

Radio call sign: international radio call sign, up to 7 characters, assigned to the vessel by its country of registry

Name: 20 characters to represent the name of the vessel

Type of ship/cargo

Dimensions of ship, to nearest meter

Location of positioning system's (e.g., GPS) antenna on board the vessel: in meters aft of bow and meters port or starboard

Type of positioning system: such as GPS, DGPS or LORAN-C.

Draught of ship: 0.1–25.5 meters

Destination: max. 20 characters

ETA (estimated time of arrival) at destination: UTC month/date hour: minute

Optional: high precision time request, a vessel can request other vessels provide a high precision UTC time and date stamp

Detailed description: Class B units

Class B transceivers are smaller, simpler and lower cost than Class A transceivers. Each consists of one VHF transmitter, two VHF Carrier Sense Time Division Multiple Access (CSTDMA) receivers, both alternating as the VHF Digital Selective Calling (DSC) receiver, and a GPS active antenna. Although the data output format supports heading information, in general units are not interfaced to a compass, so this data is seldom transmitted. Output is the standard AIS data stream at 38.400 kbit/s, as RS232 and/or NMEA formats. To prevent overloading of the available bandwidth, transmission power is restricted to 2 W, giving a range of about 5–10 mi.

Four messages are defined for class B units:

Message 14

Safety Related Message: This message is transmitted on request for the user – some transceivers have a button that enables it to be sent, or it can be sent through the software interface. It sends a pre-defined safety message.

Message 18

Standard Class B CS Position Report: This message is sent every 3 minutes where speed over ground (SOG) is less than 2 knots, or every 30 seconds for greater speeds. MMSI, time, SOG, COG, longitude, latitude, true heading

Message 19

Extended Class B Equipment Position Report: This message was designed for the SOTDMA protocol, and is too long to be transmitted as CSTDMA. However, a coast station can poll the transceiver for this message to be sent. MMSI, time, SOG, COG, longitude, latitude, true heading, ship type, dimensions.

Message 24

Class B CS Static Data Report: This message is sent every 6 minutes, the same time interval as for Class A transponders. Because of its length, this message is divided into two parts, sent within one minute of each other. This message was defined after the original AIS specifications, so some Class A units may need a firmware upgrade to be able to decode this message. MMSI, boat name, ship type, call sign, dimensions, and equipment vendor id.

Detailed description: AIS receivers

A number of manufacturers offer AIS receivers, designed for monitoring AIS traffic. These may have two receivers, for monitoring both frequencies simultaneously, or they may switch between frequencies (thereby missing messages on the other channel, but at reduced price). In general they will output RS232, NMEA, USB or UDP data for display on electronic chart plotters or computers. As well as dedicated radios, software defined radios can be set up to receive the signal

Technical specification

RF characteristics

AIS uses the globally allocated Marine Band channels 87 and 88.

AIS uses the high side of the duplex from two VHF radio "channels" (87B) and (88B)

Channel A 161.975 MHz (87B)

Channel B 162.025 MHz (88B)

The simplex channels 87A and 88A use a lower frequency so they are not affected by this allocation and can still be used as designated for the maritime mobile frequency plan.

Most AIS transmissions are composed of bursts of several messages. In these cases, between messages, the AIS transmitter must change channel.

Before being transmitted, AIS messages must be non-return-to-zero inverted (NRZI) encoded.

AIS messages are transmitted using Gaussian minimum-shift keying (GMSK) modulation. The GMSK modulator BT-product used for transmission of data should be 0.4 maximum (highest nominal value).

The GMSK coded data should frequency modulate the VHF transmitter. The modulation index should be 0.5.

The transmission bit rate is 9600 bit/s

Ordinary VHF receivers can receive AIS with the filtering disabled (the filtering destroys the GMSK data). However, the audio output from the radio would need to be then decoded. There are several PC applications that can do this.

The signal can carry a maximum on 75 kilometres

Message organization

As there are a multitude of automatic equipment transmitting AIS messages, to avoid conflict, the RF space is organized in frames. Each frame lasts exactly 1 minute and starts on each minute boundary. Each frame is divided into 2250 slots. As transmission can happen on 2 channels, there are 4500 available slots per minute.

Depending on the type and status of equipment and the status of the AIS slot map, each AIS transmitter will send out messages using one of the following schemes:

Incremental time division multiple access (ITDMA)

Random access time division multiple access (RATDMA)

Fixed access time division multiple access (FATDMA)

Self-organizing time division multiple access (SOTDMA)

The ITDMA access scheme allows a device to pre-announce transmission slots of non-repeatable character, ITDMA slots should be marked so that they are reserved for one additional frame. This allows a device to pre-announce its allocations for autonomous and continuous operation.

ITDMA is used on three occasions:

data link network entry;

temporary changes and transitions in periodical reporting intervals;

pre-announcement of safety related messages.

RATDMA is used when a device needs to allocate a slot, which has not been pre-announced. This is generally done for the first transmission slot, or for messages of a non-repeatable character.

FATDMA is used by base stations only. FATDMA allocated slots are used for repetitive messages.

SOTDMA is used by mobile devices operating in autonomous and continuous mode. The purpose of the access scheme is to offer an access algorithm which quickly resolves conflicts without intervention from controlling stations.

CHAPTER TEN

Robots

A robot is a machine especially one programmable by a computer capable of carrying out a complex series of actions automatically.[250] A robot can be guided by an external control device, or the control may be embedded within. Robots may be constructed to evoke human form, but most robots are task-performing machines, designed with an emphasis on stark functionality, rather than expressive aesthetics.

Origin Of The Term 'Robot'

'Robot' was first applied as a term for artificial automata in the 1920 play R.U.R. by the Czech writer, Karel Čapek. However, Josef Čapek was named by his brother Karel as the true inventor of the term robot. The word 'robot' itself was not new, having been in the Slavic language as robota (forced labor), a term applied to peasants obligated to compulsory service under the feudal system (see: Robot Patent). Čapek's fictional story postulated the technological creation of artificial human bodies without souls, and the old theme of the feudal robota class eloquently fit the imagination of a new class of manufactured, artificial workers.

English pronunciation of the word has evolved relatively quickly since its introduction. In the U.S. during the late '30s to early '40s the second syllable was pronounced with a long "O" like "row-boat." By the late '50s to early '60s, some were pronouncing it with a short "U" like "row-but" while others used a softer "O" like "row-bought."[251]By the '70s, its current pronunciation "row-bot" had become predominant.

[250] http://en.wikipedia,org/wiki/Robot#cite note 2
[251] http://en.wikipedia.org/wiki/Robot# cite note- 50

History of Robots

The idea of automata originates in the mythologies of many cultures around the world. Engineers and inventors from ancient civilizations, including Ancient China, Ancient Greece, and Ptolemaic Egypt attempted to build self-operating machines, some resembling animals and humans. Early descriptions of automata include the artificial doves of Archytas,[252]the artificial birds of Mozi and Lu Ban, a "speaking" automaton by Hero of Alexandria, a washstand automaton by Philo of Byzantium, and a human automaton described in the Lie Zi.[253]

Early beginnings

Many ancient mythologies, and most modern religions include artificial people, such as the mechanical servants built by the Greek god Hephaestus (Vulcan to the Romans), the clay golems of Jewish legend and clay giants of Norse legend, and Galatea, the mythical statue of Pygmalion that came to life. Since circa 400 BC, myths of Crete include Talos, a man of bronze who guarded the island from pirates.

In ancient Greece, the Greek engineer Ctesibius (c. 270 BC) "applied a knowledge of pneumatics and hydraulics to produce the first organ and water clocks with moving figures." In the 4th century BC, the Greek mathematician Archytas of Tarentum postulated a mechanical steam-operated bird he called "The Pigeon". Hero of Alexandria (10–70 AD), a Greek mathematician and inventor, created numerous user-configurable automated devices, and described machines powered by air pressure, steam and water.

The 11th century Lokapannatti tells of how the Buddha's relics were protected by mechanical robots (bhuta vahana yanta), from the kingdom of Roma visaya (Rome); until they were disarmed by King Ashoka.

In ancient China, the 3rd-century text of the Lie Zi describes an account of humanoid automata, involving a much earlier encounter between Chinese emperor King Mu of Zhou and a mechanical engineer known as Yan Shi, an

[252] http://en.wikipedia.org/wiki/Robot#cite note –needham volume volume253-16

[253]http://en.wikipedia.org/wiki/Robot#cite note –needham volume volume253-14

'artificer'. Yan Shi proudly presented the king with a life-size, human-shaped figure of his mechanical 'handiwork' made of leather, wood, and artificial organs. There are also accounts of flying automata in the Han Fei Zi and other texts, which attributes the 5th century BC Mohist philosopher Mozi and his contemporary Lu Ban with the invention of artificial wooden birds (ma yuan) that could successfully fly.

In 1066, the Chinese inventor Su Song built a water clock in the form of a tower which featured mechanical figurines which chimed the hours. His mechanism had a programmable drum machine with pegs (cams) that bumped into little levers that operated percussion instruments. The drummer could be made to play different rhythms and different drum patterns by moving the pegs to different locations.[254]

Samarangana Sutradhara, a Sanskrit treatise by Bhoja (11th century), includes a chapter about the construction of mechanical contrivances (automata), including mechanical bees and birds, fountains shaped like humans and animals, and male and female dolls that refilled oil lamps, danced, played instruments, and re-enacted scenes from Hindu mythology.[255]13th century Muslim Scientist Ismail al-Jazari created several automated devices. He built automated moving peacocks driven by hydropower. He also invented the earliest known automatic gates, which were driven by hydropower, created automatic doors as part of one of his elaborate water clocks.[256] One of al-Jazari's humanoid automata was a waitress that could serve water, tea or drinks. The drink was stored in a tank with a reservoir from where the drink drips into a bucket and, after seven minutes, into a cup, after which the waitress appears out of an automatic door serving the drink. Al-Jazari invented a hand washing automaton incorporating a flush mechanism now used in modern flush toilets. It features a female humanoid automaton standing by a basin filled with water. When the user pulls the lever, the water drains and the female automaton refills the basin.[257]

[254] http://en.wikipedia.org/wiki/Robot# cite note-NSAJA Automamata-25.

[255] http://en.wikipedia.org/wiki/Robot# cite note-NSAJA Automamata-26

[256] http://en.wikipedia.org/wiki/Robot# cite note- Hill2-13

[257] http://en.wikipedia.org/wiki/Robot# cite note- 33

Mark E. Rosheim summarizes the advances in robotics made by Muslim engineers, especially al-Jazari, as follows:

Unlike the Greek designs, these Arab examples reveal an interest, not only in dramatic illusion, but in manipulating the environment for human comfort. Thus, the greatest contribution the Arabs made, besides preserving, disseminating and building on the work of the Greeks, was the concept of practical application. This was the key element that was missing in Greek robotic science.[258]

In Renaissance Italy, Leonardo da Vinci (1452–1519) sketched plans for a humanoid robot around 1495. Da Vinci's notebooks, rediscovered in the 1950s, contained detailed drawings of a mechanical knight now known as Leonardo's robot, able to sit up, wave its arms and move its head and jaw.[259]The design was probably based on anatomical research recorded in his Vitruvian Man. It is not known whether he attempted to build it. According to Encyclopeadia Britannica, Leonardo da Vinci may have been influenced by the classic automata of al-Jazari.

In Japan, complex animal and human automata were built between the 17th to 19th centuries, with many described in the 18th century Karakuri zui (Illustrated Machinery, 1796). One such automaton was the karakuri ningyō, a mechanized puppet.[260] Different variations of the karakuri existed: the Butai karakuri, which were used in theatre, the Zashiki karakuri, which were small and used in homes, and the Dashi karakuri which were used in religious festivals, where the puppets were used to perform reenactments of traditional myths and legends.

In France, between 1738 and 1739, Jacques de Vaucanson exhibited several life-sized automatons: a flute player, a pipe player and a duck. The mechanical duck could flap its wings, crane its neck, and swallow food from the exhibitor's hand, and it gave the illusion of digesting its food by excreting matter stored in a hidden compartment.

[258] http://en.wikipedia.org/wiki/Robot# cite note- 34
[259] http://en.wikipedia.org/wiki/Robot# cite note- 6
[260] http://en.wikipedia.org/wiki/Robot# cite note- 37

The word 'robot' was first used to denote a fictional humanoid in a 1920 Czech-language play R.U.R. (Rossumovi Univerzální Roboti Rossum's Universal Robots) by Karel Čapek, though it was Karel's brother Josef Čapek who was the word's true inventor.[261] Electronics evolved into the driving force of development with the advent of the first electronic autonomous robots created by William Grey Walter in Bristol, England in 1948, as well as Computer Numerical Control (CNC) machine tools in the late 1940s by John T. Parsons and Frank L. Stulen

Robots can be autonomous or semi-autonomous and range from humanoids such as Honda's Advanced Step in Innovative Mobility (ASIMO) and TOSY's TOSY Ping Pong Playing Robot (TOPIO) to industrial robots, medical operating robots, patient assist robots, dog therapy robots, collectively programmed swarm robots, UAV drones such as General Atomics MQ-1 Predator, and even microscopic nano robots. By mimicking a lifelike appearance or automating movements, a robot may convey a sense of intelligence or thought of its own. Autonomous things are expected to proliferate in the future, with home robotics and the autonomous car as some of the main drivers.[262]

The branch of technology that deals with the design, construction, operation, and application of robots,[263] as well as computer systems for their control, sensory feedback, and information processing is robotics.

These technologies deal with automated machines that can take the place of humans in dangerous environments or manufacturing processes, or resemble humans in appearance, behavior, or cognition. Many of today's robots are inspired by nature contributing to the field of bio-inspired robotics. These robots have also created a newer branch of robotics: soft robotics.

From the time of ancient civilization, there have been many accounts of user-configurable automated devices and even automata resembling humans and other animals, designed primarily as entertainment. As mechanical techniques developed

[261] http://en.wikipedia,org/wiki/Robot#cite note 7
[262] http://en.wikipedia,org/wiki/Robot#cite note 3
[263] http://en.wikipedia,org/wiki/Robot#cite note 7

through the Industrial age, there appeared more practical applications such as automated machines, remote-control and wireless remote-control.

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The first modern digital and programmable robot was invented by George Devol in 1954 and spawned his seminal robotics company, Unimation. The first Unimate was sold to General Motors in 1961 where it lifted pieces of hot metal from die casting machines at the Inland Fisher Guide Plant in the West Trenton section of Ewing Township, New Jersey.[264]

Robots have replaced humans in performing repetitive and dangerous tasks which humans prefer not to do, or are unable to do because of size limitations, or which take place in extreme environments such as outer space or the bottom of the sea. There are concerns about the increasing use of robots and their role in society. Robots are blamed for rising technological unemployment as they replace workers in increasing numbers of functions.[265]The use of robots in military combat raises ethical concerns. The possibilities of robot autonomy and potential repercussions have been addressed in fiction and may be a realistic concern in the future.

The word robot can refer to both physical robots and virtual software agents, but the latter are usually referred to as bots.[266]There is no consensus on which machines qualify as robots but there is general agreement among experts, and the public, that robots tend to possess some or all of the following abilities and functions: accept electronic programming, process data or physical perceptions electronically, operate autonomously to some degree, move around, operate physical parts of itself or physical processes, sense and manipulate their environment, and exhibit intelligent behavior, especially behavior which mimics humans or other animals. Closely related to the concept of a robot is the field of Synthetic Biology, which studies entities whose nature is more comparable to beings than to machines. The future of robotics

[264] http://en.wikipedia,org/wiki/Robot#cite note 8

[265] http://en.wikipedia,org/wiki/Robot#cite note 7

[266] http://en.wikipedia,org/wiki/Robot#cite note 11

In this introduction to robotics, we take a look at what robots are, how they're currently used, and how they might shape the world in the future.

WHAT IS ROBOTICS?

Robotics is the discipline of creating robots. It's a multidisciplinary field where computer science, engineering, and technology all meet. Those working in robotics focus on the design, construction, operation, and use of robots in a host of different settings.

Traditionally, the field of robotics canters on creating robots to perform simple or repetitive tasks at scale or to function in hazardous conditions where humans would otherwise be unable to work.

However, recent developments in machine learning and artificial intelligence means that we may see an increase in human-to-robot interactions in the future.

The robotics industry is expected to grow significantly over the coming years. Estimates suggest that the sector could be worth as much as $260 billion by 2030. Much of this growth will come from professional services robots that perform useful tasks for humans, such as cleaning, delivering, and transporting.

For those looking to get a more thorough introduction to robotics, our online course from the University of Reading explores the history, anatomy and intelligence of robots.

Types Of Robots

Although the concept of robots has existed for many years, it's only been in the last few decades that they've grown in complexity and use. Nowadays, there are many practical applications for robots across a wide range of fields.

As discussed in our open step on the applications of robots, some of these types of robots include:

Industrial. Perhaps the most common use of robots is for simple and repetitive industrial tasks. Examples include assembly line processes, picking and packing, welding, and similar functions. They offer reliability, accuracy, and speed.

Military. More recent developments mean that military forces worldwide use robots in areas such as UAVs (Unmanned Aerial Vehicle), UGVs (Unmanned Ground Vehicle), triage and surveillance.

Service. One of the main growth areas in robotics is in the personal service industry. Uses include for manual tasks such as dispensing food and cleaning.

Exploration. We often use robots to reach hostile or otherwise inaccessible areas. A good example of exploratory robots is in space exploration, such as the Curiosity Rover on Mars.

Hazardous environments. Again, certain environments can be dangerous for humans to enter, such as disaster areas, places with high radiation, and extreme environments.

Medical. In the world of healthcare, MedTech robots are being used in all kinds of ways. Whether it's managing laboratory specimens or assisting with surgery, rehabilitation, or physiotherapy.

Entertainment. Increasingly (particularly during the pandemic), people are buying robots for enjoyment. There are several popular toy robots, and there are even robot restaurants and giant robot statues.

Advantages And Disadvantages Of Robots

The field of robotics offers solutions to many different problems. As we'll see, the future of robots could change the world we live in. However, that doesn't mean there aren't downsides to the technology.

As explored on our open step from the University of Reading, there are various pros and cons of using robots in our modern world:

Advantages Of Robots

They can offer increased productivity, efficiency, quality and consistency in certain settings.

Unlike humans, robots don't get bored.

Until they wear out, they can repeat the same process continuously.

They can be very accurate, even to fractions of an inch, making them particularly useful in the manufacturing of microelectronics.

Robots can work in environments that are unsafe for humans, such as with dangerous chemicals or in areas of high radiation.

They don't have physical or environmental needs in the same way humans do.

Some robots have sensors and actuators which are more capable than humans.

Disadvantages Of Robots

In some industries, robots are replacing human jobs, which can create economic problems.

On the whole, robots can only do what they are told to do, meaning they can't improvise (although AI and machine learning is changing this).

Current robotics technology means that most machines are less dexterous than humans and can't compete with a human's ability to understand what they can see. Although experts are working on developing robots that can better sense the world.

Robots with practical applications are generally expensive in terms of the initial cost, maintenance, the need for extra components and the need to be programmed to do the task.

The Future Of Robotics: Will Robots Take Over The World?

Robots are already all around us, whether it's the automated machines that assemble our vehicles or the virtual assistants that use conversational interfaces to help us around the house. Yet as we've seen, they're not currently suitable for all areas of life. But will that change in the future?

Despite fears of an AI takeover, where machines replace humans as the dominant intelligence on the planet, such a scenario seems unlikely. However, business network PwC predicts that up to 30% of jobs could be automated by robots by the mid-2030s.

Other reports suggest that the stock of robots worldwide could reach 20 million by 2030, with automated workers taking up to 51 million jobs in the next 10 years. So, while they may not take over the world, we can expect to see more robots in our daily lives.

How Robots Will Change The World

According to a report from McKinsey, automation and machines will see a shift in the way we work. They predict that across Europe, workers may need different skills to find work. Their model shows that activities that require mainly physical and manual skills will decline by 18% by 2030, while those requiring basic cognitive skills will decline by 28%.

Workers will need technological skills, and there will be an even greater need for those with expertise in STEM. Similarly, many roles will require socioemotional skills, particularly in roles where robots aren't good substitutes, such as care giving and teaching.

We may also see robots as a more integral part of our daily routine. In our homes, many simple tasks such as cooking and cleaning may be totally automated. Similarly, with robots that can use computer vision and natural language processing, we may see machines that can interact with the world more, such as self-driving cars and digital assistants.

Robotics may also shape the future of medicine. Surgical robots can perform extremely precise operations, and with advances in AI, could eventually carry out surgeries independently.

The ability for machines and robots to learn could give them an even more diverse range of applications. Future robots that can adapt to their surroundings, master new processes, and alter their behavior would be suited to more complex and dynamic tasks.

Ultimately, robots have the potential to enhance our lives. As well as shouldering the burden of physically demanding or repetitive tasks, they may be able to improve healthcare, make transport more efficient, and give us more freedom to pursue creative endeavors.

Interested In Robotics?

If you're an aspiring roboticist, there are several ways you can get started in the industry. You'll need to work on some key skills, such as mathematics, science, programming, and problem-solving. You need to understand the basics of robotics and get some practical experience programming and building them and how they connect motors, add sensors and write algorithms to build our very own robot buggy, this usually involves deep learning to master areas of AI and machine learning, such as the use of robotics in healthcare.

Programming

There are many types of robots; they are used in many different environments and for many different uses. Although being very diverse in application and form, they all share three basic similarities when it comes to their construction:

Robots all have some kind of mechanical construction, a frame, form or shape designed to achieve a particular task. For example, a robot designed to travel across heavy dirt or mud, might use caterpillar tracks. The mechanical aspect is mostly the creator's solution to completing the assigned task and dealing with the physics of the environment around it. Form follows function.

Robots have electrical components that power and control the machinery. For example, the robot with caterpillar tracks would need some kind of power to move the tracker treads. That power comes in the form of electricity, which will have to travel through a wire and originate from a battery, a basic electrical circuit. Even petrol powered machines that get their power mainly from petrol still require an electric current to start the combustion process which is why most petrol-powered machines like cars, have batteries. The electrical aspect of robots is used for movement (through motors), sensing (where electrical signals are used to measure things like heat, sound, position, and energy status) and operation (robots need some level of electrical energy supplied to their motors and sensors in order to activate and perform basic operations)

All robots contain some level of computer programming code. A program is how a robot decides when or how to do something. In the caterpillar track example, a robot that needs to move across a muddy road may have the correct mechanical construction and receive the correct amount of power from its battery, but would not go anywhere without a program telling it to move. Programs are the core essence of a robot, it could have excellent mechanical and electrical construction, but if its program is poorly constructed its performance will be very poor (or it may not perform at all). There are three different types of robotic programs: remote control, artificial intelligence and hybrid. A robot with remote control programming has a pre-existing set of commands that it will only perform if and when it receives a signal from a control source, typically a human being with a remote control. It is perhaps more appropriate to view devices controlled primarily by human commands as falling in the discipline of automation rather than robotics. Robots that use artificial intelligence interact with their environment on their own without a control source, and can determine reactions to objects and problems they encounter using their pre-existing programming. Hybrid is a form of programming that incorporates both AI and RC functions in them.

APPLICATIONS

As more and more robots are designed for specific tasks, this method of classification becomes more relevant. For example, many robots are designed for assembly work, which may not be readily adaptable for other applications. They are termed as "assembly robots". For seam welding, some suppliers provide complete welding systems with the robot i.e., the welding equipment along with other material handling facilities like turntables, etc. as an integrated unit. Such an integrated robotic system is called a "welding robot" even though its discrete manipulator unit could be adapted to a variety of tasks. Some robots are specifically designed for heavy load manipulation, and are labeled as "heavy-duty robots".

Current and potential applications of robots:

Military robots.

Industrial robots. Robots are increasingly used in manufacturing (since the 1960s). According to the Robotic Industries Association US data, in 2016 automotive industry was the main customer of industrial robots with 52% of total sales. In the auto industry, they can amount for more than half of the "labor". There are even "lights off" factories such as an IBM keyboard manufacturing factory in Texas that was fully automated as early as 2003.

Cobots (collaborative robots).

Construction robots. Construction robots can be separated into three types: traditional robots, robotic arm, and robotic exoskeleton.

Agricultural robots (Ag Robots).The use of robots in agriculture is closely linked to the concept of AI-assisted precision agriculture and drone usage.1996-1998 research also proved that robots can perform a herding tasks

Medical robots of various types (such as da Vinci Surgical System and Hospital).

Kitchen automation. Commercial examples of kitchen automation are Flippy (burgers), Zume Pizza (pizza), Cafe X (coffee), Makr Shakr (cocktails), Frobot (frozen yogurts) and Sally (salads). Home examples are Rotimatic (flatbreads baking) and Boris (dishwasher loading).

Robot combat for sport – hobby or sport event where two or more robots fight in an arena to disable each other. This has developed from a hobby in the 1990s to several TV series worldwide, they also help in Clean-up of contaminated areas, such as toxic waste or nuclear facilities.

NANOROBOTICS

Nanoid robotics, or for short, **nanorobotics** or **nanobotics**, is an emerging technology field creating machines or robots whose components are at or near the scale of a nanometer (10^{-9} meters).[267] More specifically, nanorobotics (as opposed to microrobotics) refers to the nanotechnology engineering discipline of designing and building nanorobots with devices ranging in size from 0.1 to 10 micrometres and constructed of nanoscale or molecular components.[4][5] The terms nanobot, nanoid, nanite, nanomachine and nanomite have also been used to describe such devices currently under research and development.[268]

Nanomachines are largely in the research and development phase,[269] but some primitive molecular machines and nanomotors have been tested. An example is a sensor having a switch approximately 1.5 nanometres' across, able to count specific molecules in the chemical sample. The first useful applications of nanomachines may be in nanomedicine. For example,[270] biological machines could be used to

[267] *Sierra, D. P.; Weir, N. A.; Jones, J. F. (2005). "A review of research in the field of nanorobotics" (PDF). U.S. Department of Energy – Office of Scientific and Technical Information Oak Ridge, TN. SAND2005-6808: 1–50. Doi:10.2172/875622. OSTI 875622.*

[268] *^ Cerofolini, G.; Amato, P.; Asserini, M.; Mauri, G. (2010). "A Surveillance System for Early-Stage Diagnosis of Endogenous Diseases by Swarms of Nanobots". Advanced Science Letters. 3 (4): 345–352. Doi:10.1166/asl.2010.1138*

[269] *Wang, J. (2009). "Can Man-Made Nanomachines Compete with Nature Biomotors?". ACS Nano. 3 (1): 4–9. Doi:10.1021/nn800829k. PMID 19206241*

[270] *Amrute-Nayak, M.; Diensthuber, R. P.; Steffen, W.; Kathmann, D.; Hartmann, F. K.; Fedorov, R.; Urbanke, C.; Manstein, D. J.; Brenner, B.; Tsiavaliaris, G. (2010). "Targeted Optimization of a*

identify and destroy cancer cells.[271] Another potential application is the detection of toxic chemicals, and the measurement of their concentrations, in the environment. Rice University has demonstrated a single-molecule car developed by a chemical process and including Buckminster fullerenes (buckyballs) for wheels. It is actuated by controlling the environmental temperature and by positioning a scanning tunnelling microscope tip.

Another definition is a robot that allows precise interactions with nanoscale objects, or can manipulate with nanoscale resolution. Such devices are more related to microscopy or scanning probe microscopy, instead of the description of nanorobots as molecular machines. Using the microscopy definition, even a large apparatus such as an atomic force microscope can be considered a nanorobotic instrument when configured to perform nanomanipulation. For this viewpoint, macroscale robots or microrobots that can move with nanoscale precision can also be considered nanorobots.

NANOROBOTIC THEORY

According to Richard Feynman, it was his former graduate student and collaborator Albert Hibbs who originally suggested to him (circa 1959) the idea of a medical use for Feynman's theoretical micro-machines (see biological machine). Hibbs suggested that certain repair machines might one day be reduced in size to the point that it would, in theory, be possible to (as Feynman put it) "swallow the surgeon". The idea was incorporated into Feynman's 1959 essay There's Plenty of Room at the Bottom.

Since nano-robots would be microscopic in size, it would probably be necessary for very large numbers of them to work together to perform microscopic and macroscopic tasks. These nano-robot swarms, both those unable to replicate (as

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Protein Nanomachine for Operation in Biohybrid Devices". Angewandte Chemie. 122 (2): 322–326. Doi:10.1002/ange.200905200. PMID 19921669

[271] Jump up to:[a] [b] *Patel, G. M.; Patel, G. C.; Patel, R. B.; Patel, J. K.; Patel, M. (2006). "Nanorobot: A versatile tool in nanomedicine". Journal of Drug Targeting. 14 (2): 63–67. Doi:10.1080/10611860600612862. PMID 16608733. S2CID 25551052.*

in utility fog) and those able to replicate unconstrained in the natural environment (as in grey goo and synthetic biology), are found in many science fiction stories, such as the Borg nano-probes in Star Trek and The Outer Limits episode "The New Breed". Some proponents of nano-robotics, in reaction to the grey goo scenarios that they earlier helped to propagate, hold the view that nano-robots able to replicate outside of a restricted factory environment do not form a necessary part of a purported productive nanotechnology, and that the process of self-replication, were it ever to be developed, could be made inherently safe. They further assert that their current plans for developing and using molecular manufacturing do not in fact include free-foraging replicators.[272]

A detailed theoretical discussion of nanorobotics, including specific design issues such as sensing, power communication, navigation, manipulation, locomotion, and onboard computation, has been presented in the medical context of nanomedicine by Robert Freitas.[273] Some of these discussions[remain at the level of unbuildable generality and do not approach the level of detailed engineering.

Swarm robotics

Autonomous drones.

Sports field line marking.

Educational robotics. Robots such as LEGO Mind storms and Ozobots are used to teach coding, mathematics, and creative skills.

Legal And Ethical Implication Of Robotics

A document with a proposal on Nano biotech development using open design technology methods, as in open-source hardware and open-source software,

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[272]R.A. Freitas Jr., Nanomedicine, Vol. I: Basic Capabilities, Landes Bioscience, Georgetown TX, 1999; http://www.nanomedicine.com/NMI.htm Archived 2015-08-14 at the Wayback Machine

[273]R.A. Freitas Jr., Nanomedicine, Vol. I: Basic Capabilities, Landes Bioscience, Georgetown TX, 1999; http://www.nanomedicine.com/NMI.htm Archived 2015-08-14 at the Wayback Machine.

has been addressed to the United Nations General Assembly.[274] According to the document sent to the United Nations, in the same way that open source has in recent years accelerated the development of computer systems, a similar approach should benefit the society at large and accelerate Nano robotics development. The use of Nano biotechnology should be established as a human heritage for the coming generations, and developed as an open technology based on ethical practices for peaceful purposes. Open technology is stated as a fundamental key for such an aim.

NANO ROBOT RACE

In the same ways that technology research and development drove the space race and nuclear arms race, a race for nanorobots is occurring.[275] There is plenty of ground allowing nanorobots to be included among the emerging technologies. Some of the reasons are that large corporations, such as General Electric, Hewlett-Packard, Synopsys, Northrop Grumman and Siemens have been recently working in the development and research of nanorobots;[276] surgeons are getting involved and starting to propose ways to apply nanorobots for common medical procedures;[277] universities and research institutes were granted funds by government agencies exceeding $2 billion towards research developing nanodevices for medicine;[278] bankers are also strategically investing with the intent to acquire

[274] *Cavalcanti, A. (2009). "Nanorobot Invention and Linux: The Open Technology Factor – An Open Letter to UNO General Secretary" (PDF). CANNXS Project. 1 (1): 1–4.*

[275] *Rosso, F.; Barbarisi, M.; Barbarisi, A. (2011). Technology for Biotechnology. Biotechnology in Surgery. Pp. 61–73. Doi:10.1007/978-88-470-1658-3_4. ISBN 978-88-470-1657-6.*

[276] *Murday, J. S.; Siegel, R. W.; Stein, J.; Wright, J. F. (2009). "Translational nanomedicine: Status assessment and opportunities". Nanomedicine: Nanotechnology, Biology and Medicine. 5 (3): 251–273. Doi:10.1016/j.nano.2009.06.001. PMID 19540359.*

[277] *Cuschieri, A. (2005). "Laparoscopic surgery: current status, issues and future developments". Surgeon. 3 (3): 125–138. Doi:10.1016/S1479-666X(05)80032-0. PMID 16075996.*

[278] *Roco, M. C. (2003). "Nanotechnology: convergence with modern biology and medicine". Current Opinion in Biotechnology (Submitted manuscript). 14 (3): 337–346. Doi:10.1016/S0958-1669(03)00068-5. PMID 12849790.*

beforehand rights and royalties on future nanorobots commercialisation.[279] Some aspects of nanorobot litigation and related issues linked to monopoly have already arisen.[280] A large number of patents has been granted recently on nanorobots, done mostly for patent agents, companies specialized solely on building patent portfolios, and lawyers. After a long series of patents and eventually litigations, see for example the invention of radio, or the war of currents, emerging fields of technology tend to become a monopoly, which normally is dominated by large corporations.

Manufacturing approaches

Manufacturing nanomachines assembled from molecular components is a very challenging task. Because of the level of difficulty, many engineers and scientists continue working cooperatively across multidisciplinary approaches to achieve breakthroughs in this new area of development. Thus, it is quite understandable the importance of the following distinct techniques currently applied towards manufacturing nanorobots:

BIOCHIP

The joint use of nanoelectronics, photolithography, and new biomaterials provides a possible approach to manufacturing nanorobots for common medical uses, such as surgical instrumentation, diagnosis, and drug delivery.[281] This method for manufacturing on nanotechnology scale is in use in the electronics industry since 2008.[282] So, practical nanorobots should be integrated as nanoelectronics devices,

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[279] *Smith, D. M.; Goldstein, D. S.; Heideman, J. (2007). "Reverse Mergers and Nanotechnology". Nanotechnology Law & Business. 4 (3).*

[280] *Gilbert, R. J.; Newbery, D. M. G. (June 1982). "Preemptive Patenting and the Persistence of Monopoly". American Economic Review. 72 (3): 514–526. JSTOR 1831552.*

[281] *Fisher, B. (2008). "Biological Research in the Evolution of Cancer Surgery: A Personal Perspective". Cancer Research. 68 (24): 10007–10020. Doi:10.1158/0008-5472.CAN-08-0186. PMID 19074862.Cavalcanti, A.; Shirinzadeh*

[282] *Cale, T. S.; Lu, J. Q.; Gutmann, R. J. (2008). "Three-Dimensional Integration in Microelectronics: Motivation, Processing, and Thermomechanical Modelling". Chemical Engineering Communications. 195 (8): 847–888. Doi:10.1080/00986440801930302. S2CID 95022083*

which will allow tele-operation and advanced capabilities for medical instrumentation.

Nubots

A nucleic acid robot (nubot) is an organic molecular machine at the nanoscale.[283] DNA structure can provide means to assemble 2D and 3D nanomechanical devices. DNA based machines can be activated using small molecules, proteins and other molecules of DNA.[284] Biological circuit gates based on DNA materials have been engineered as molecular machines to allow in-vitro drug delivery for targeted health problems.[285] Such material based systems would work most closely to smart biomaterial drug system delivery,[286] while not allowing precise in vivo teleoperation of such engineered prototypes.

Surface-bound systems

Several reports have demonstrated the attachment of synthetic molecular motors to surfaces.[287] These primitive nanomachines have been shown to undergo machine-like motions when confined to the surface of a macroscopic material. The surface

[283] *Wong, P. C.; Wong, K. K.; Foote, H. (2003). "Organic data memory using the DNA approach". Communications of the ACM. 46: 95–98. Citeseerx 10.1.1.302.6363. Doi:10.1145/602421.602426. S2CID 15443572.*

[284] *Yin, P.; Choi, H. M. T.; Calvert, C. R.; Pierce, N. A. (2008). "Programming biomolecular self-assembly pathways". Nature. 451 (7176): 318–322. Bibcode:2008Natur. 451..318Y. Doi:10.1038/nature06451. PMID 18202654. S2CID 4354536.*

[285] *Douglas, Shawn M.; Bachelet, Ido; Church, George M. (17 February 2012). "A logic-gated nanorobot for targeted transport of molecular payloads". Science. 335 (6070): 831–834. Bibcode:2012Sci...*
335..831D. Doi:10.1126/science.1214081. PMID 22344439. S2CID 9866509.

[286] *Jin, S.; Ye, K. (2007). "Nanoparticle-Mediated Drug Delivery and Gene Therapy". Biotechnology Progress. 23 (1): 32–41. Doi:10.1021/bp060348j. PMID 17269667. S2CID 9647481.*

[287] *Carroll, G. T.; London, G. B.; Landaluce, T. F. N.; Rudolf, P.; Feringa, B. L. (2011). "Adhesion of Photon-Driven Molecular Motors to Surfacesvia1,3-Dipolar Cycloadditions: Effect of Interfacial Interactions on Molecular Motion" (PDF). ACS Nano. 5 (1): 622–630. Doi:10.1021/nn102876j. PMID 21207983.*

anchored motors could potentially be used to move and position nanoscale materials on a surface in the manner of a conveyor belt.

Positional nano assembly

Nanofactory Collaboration,[288] founded by Robert Freitas and Ralph Merkle in 2000 and involving 23 researchers from 10 organizations and 4 countries, focuses on developing a practical research agenda[289] specifically aimed at developing positionally-controlled diamond mechano synthesis and a diamondoid nanofactory that would have the capability of building diamondoid medical nanorobots.

Biohybrids

The emerging field of bio-hybrid systems combines biological and synthetic structural elements for biomedical or robotic applications. The constituting elements of bio-nanoelectromechanical systems (BioNEMS) are of nanoscale size, for example DNA, proteins or nanostructured mechanical parts. Thiol-ene e-beams resist allow the direct writing of nanoscale features, followed by the functionalization of the natively reactive resist surface with biomolecules.[290] Other approaches use a biodegradable material attached to magnetic particles that allow them to be guided around the body.[291]

Bacteria-based

[288] "Nanofactory Collaboration". *Molecularassembler.com*.

[289] "Nanofactory Technical Challenges". *Molecularassembler.com*.

[290] *Shafagh, Reza; Vastesson, Alexander; Guo, Weijin; van der Wijngaart, Wouter; Haraldsson, Tommy (2018). "E-Beam Nanostructuring and Direct Click Biofunctionalization of Thiol–Ene Resist". ACS Nano. 12 (10): 9940–9946. Doi:10.1021/acsnano.8b03709. PMID 30212184. S2CID 52271550.*

[291] Multifunctional biohybrid magnetite microrobots for imaging-guided therapy

This approach proposes the use of biological microorganisms, like the bacterium Escherichia coli and Salmonella typhimurium.[292] Thus the model uses a flagellum for propulsion purposes. Electromagnetic fields normally control the motion of this kind of biological integrated device.[293] Chemists at the University of Nebraska have created a humidity gauge by fusing a bacterium to a silicon computer chip.

Virus-based

Retroviruses can be retrained to attach to cells and replace DNA. They go through a process called reverse transcription to deliver genetic packaging in a vector. Usually, these devices are Pol – Gag genes of the virus for the Capsid and Delivery system. This process is called retroviral gene therapy, having the ability to re-engineer cellular DNA by usage of viral vectors.[294] This approach has appeared in the form of retroviral, adenoviral, and lentiviral gene delivery systems.[295] These gene therapy vectors have been used in cats to send genes into the genetically modified organism (GMO), causing it to display the trait. [296]

3D printing

3D printing is the process by which a three-dimensional structure is built through the various processes of additive manufacturing. Nanoscale 3D printing involves many of the same process, incorporated at a much smaller scale. To print a structure in the 5-400 µm scale, the precision of the 3D printing machine needs to be

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[292] *Park, Sung Jun; Park, Seung-Hwan; Cho, S.; Kim, D.; Lee, Y.; Ko, S.; Hong, Y.; Choy, H.; Min, J.; Park, J.; Park, S. (2013). "New paradigm for tumor theranostic methodology using bacteria-based microrobot". Scientific Reports. 3: 3394. Bibcode:2013natsr...3E3394P. Doi:10.1038/srep03394. PMC 3844944. PMID 24292152.*

[293] *Sakar, Mahmud (2010). "Micro Bio Robots for Single Cell" (PDF).*

[294] Perkel, Jeffrey M. Viral Mediated Gene Delivery. Sciencemag.org

[295] Jump up to:[a] [b] *Nano Robot by 3D Printing (Seoul National University, Korea).wmv, 2012-01-29, retrieved 2015-12-04*

[296] *Jha, Alok (11 September 2011). "Glow cat: fluorescent green felines could help study of HIV". The Guardian.*

improved greatly. A two-step process of 3D printing, using a 3D printing and laser etched plates method was incorporated as an improvement technique.[297] To be more precise at a nanoscale, the 3D printing process uses a laser etching machine, which etches the details needed for the segments of nanorobots into each plate. The plate is then transferred to the 3D printer, which fills the etched regions with the desired nanoparticle. The 3D printing process is repeated until the nanorobot is built from the bottom up.

This 3D printing process has many benefits. First, it increases the overall accuracy of the printing process. Second, it has the potential to create functional segments of a nanorobot.[298] The 3D printer uses a liquid resin, which is hardened at precisely the correct spots by a focused laser beam. The focal point of the laser beam is guided through the resin by movable mirrors and leaves behind a hardened line of solid polymer, just a few hundred nanometers wide. This fine resolution enables the creation of intricately structured sculptures as tiny as a grain of sand. This process takes place by using photoactive resins, which are hardened by the laser at an extremely small scale to create the structure. This process is quick by nanoscale 3D printing standards. Ultra-small features can be made with the 3D micro-fabrication technique used in multiphoton photopolymerisation. This approach uses a focused laser to trace the desired 3D object into a block of gel. Due to the nonlinear nature of photo excitation, the gel is cured to a solid only in the places where the laser was focused while the remaining gel is then washed away. Feature sizes of under 100 nm are easily produced, as well as complex structures with moving and interlocked parts.[299]

Challenges in designing nanorobots

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[297] *Nano Robot by 3D Printing (Seoul National University, Korea).wmv, 2012-01-29, retrieved 2015-12-04*

[298] Ibid 27

[299] *Vlassov, Sergei; Oras, Sven; Antsov, Mikk; Butikova, Jelena; Lõhmus, Rünno; Polyakov, Boris (2018-03-16). "Low-friction nanojoint prototype". Nanotechnology. 29 (19): 195707. Doi:10.1088/1361-6528/aab163. ISSN 0957-4484. PMID 29469059.*

There are number of challenges and problems that should be addressed when designing and building nanoscale machines with movable parts. The most obvious one is the need of developing very fine tools and manipulation techniques capable of assembling individual nanostructures with high precision into operational device. Less evident challenge is related to peculiarities of adhesion and friction on nanoscale. It is impossible to take existing design of macroscopic device with movable parts and just reduce it to the nanoscale. Such approach will not work due to high surface energy of nanostructures, which means that all contacting parts will stick together following the energy minimization principle. The adhesion and static friction between parts can easily exceed the strength of materials, so the parts will break before they start to move relative to each other. This leads to the need to design movable structures with minimal contact area [300]

In spite of the fast development of nanorobots, most of the nanorobots designed for drug delivery purposes, there is "still a long way to go before their commercialization and clinical applications can be achieved."[301]

POTENTIAL USES OF NANOTECHNOLOGY.

Nanomedicine

Potential uses for nanorobotics in medicine include early diagnosis and targeted drug-delivery for cancer, biomedical instrumentation, surgery, pharmacokinetics, monitoring of diabetes,[302] and health care.[303]

[300] *Vlassov, Sergei; Oras, Sven; Antsov, Mikk; Butikova, Jelena; Lõhmus, Rünno; Polyakov, Boris (2018-03-16). "Low-friction nanojoint prototype". Nanotechnology. 29 (19): 195707. Doi:10.1088/1361-6528/aab163. ISSN 0957-4484. PMID 29469059.*

[301] Nanotechnology in Cancer. Nano.cancer.gov

[302] *Donnelly, R. (2007). "Wellness engineering and health management: A video interview with Harold H. Szu". SPIE Newsroom. Doi:10.1117/2.3200708.0002.*

[303] *Leary, S. P.; Liu, C. Y.; Apuzzo, M. L. J. (2006). "Toward the Emergence of Nanoneurosurgery: Part III???Nanomedicine: Targeted Nanotherapy, Nanosurgery, and Progress Toward the*

In such plans, future medical nanotechnology is expected to employ nanorobots injected into the patient to perform work at a cellular level. Such nanorobots intended for use in medicine should be non-replicating, as replication would needlessly increase device complexity, reduce reliability, and interfere with the medical mission.

Nanotechnology provides a wide range of new technologies for developing customized means to optimize the delivery of pharmaceutical drugs. Today, harmful side effects of treatments such as chemotherapy are commonly a result of drug delivery methods that don't pinpoint their intended target cells accurately.[304] Researchers at Harvard and MIT, however, have been able to attach special RNA strands, measuring nearly 10 nm in diameter, to nanoparticles, filling them with a chemotherapy drug. These RNA strands are attracted to cancer cells. When the nanoparticle encounters a cancer cell, it adheres to it, and releases the drug into the cancer cell.[305] This directed method of drug delivery has great potential for treating cancer patients while avoiding negative effects (commonly associated with improper drug delivery).[306] The first demonstration of nanomotors operating in living organisms was carried out in 2014 at University of California, San Diego. MRI-guided nanocapsules are one potential precursor to nanorobots.[307]

Another useful application of nanorobots is assisting in the repair of tissue cells alongside white blood cells.[308] Recruiting inflammatory cells or white blood cells

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Realization of Nanoneurosurgery". Neurosurgery. 58 (6): 1009–1026. Doi:10.1227/01.NEU.0000217016.79256.16. PMID 16723880. S2CID 33235348.

[304]Jump up to:[a] [b] *Bhowmik, Debjit (2009). "Role of Nanotechnology in novel Drug Delivery system" (PDF). Journal of Pharmaceutical Science and Technology. 1 (1): 20–35. Archived from the original (PDF) on 2015-09-24. Retrieved 2015-03-08.*

[305]Bullis, Kevin (April 29, 2008). "Nano RNA Delivery." *MIT Technology Review*.

[306]*Gao, W.; Wang, J. (2014). "Synthetic micro/nanomotors in drug delivery". Nanoscale. 6 (18): 10486–94. Bibcode:2014Nanos...610486G. Doi:10.1039/C4NR03124E. PMID 25096021.*

[307]*Vartholomeos, P.; Fruchard, M.; Ferreira, A.; Mavroidis, C. (2011). "MRI-Guided Nanorobotic Systems for Therapeutic and Diagnostic Applications" (PDF). Annu Rev Biomed Eng. 13: 157–84. Doi:10.1146/annurev-bioeng-071910-124724. PMID 21529162. S2CID 32852758.*

[308]Jump up to: Casal, Arancha *et al.* (2004) "Nanorobots as Cellular Assistants in Inflammatory Responses". Nanorobotdesign.com

(which include neutrophil granulocytes, lymphocytes, monocytes, and mast cells) to the affected area is the first response of tissues to injury.[309] Because of their small size, nanorobots could attach themselves to the surface of recruited white cells, to squeeze their way out through the walls of blood vessels and arrive at the injury site, where they can assist in the tissue repair process. Certain substances could possibly be used to accelerate the recovery.

The science behind this mechanism is quite complex. Passage of cells across the blood endothelium, a process known as transmigration, is a mechanism involving engagement of cell surface receptors to adhesion molecules, active force exertion and dilation of the vessel walls and physical deformation of the migrating cells. By attaching themselves to migrating inflammatory cells, the robots can in effect "hitch a ride" across the blood vessels, bypassing the need for a complex transmigration mechanism of their own.[310]

As of 2016, in the United States, Food and Drug Administration (FDA) regulates nanotechnology on the basis of size.[311]

Nanocomposite particles that are controlled remotely by an electromagnetic field was also developed.[312] This series of nanorobots that are now enlisted in the Guinness World Records,[313] can be used to interact with the biological cells. Scientists suggest that this technology can be used for the treatment of cancer.[314]

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[309] C. Janeway (ed.) (2001) *Immun Biology, the Immune System in Health and Disease*. Garland Pub; 5th ed. ISBN 0-8153-3642-X.

[310] ibid

[311] FDA (2011) Considering Whether an FDA-Regulated Product Involves the Application of Nanotechnology, Guidance for Industry, Draft Guidance.

[312] Jump up to: *"Smallest medical robot for the Guinness World Records: Nanorobots to tackle drug delivery for cancer treatment". Sciencedaily. Retrieved 2018-08-29.*

[313] Ibid 50

[314] *"Smallest medical robot to help treat cancer - Times of India". The Times of India. Retrieved 2018-08-29.*

Nanates

The Nanites are characters on the TV show Mystery Science Theater 3000. They're self-replicating, bio-engineered organisms that work on the ship and reside in the SOL's computer systems. They made their first appearance in Season 8. Nanites are used in a number of episodes in the Netflix series "Travelers". They be programmed and injected into injured people to perform repairs. First appearance in season 1

Nanites also feature in the Rise of Iron 2016 expansion for Destiny in which SIVA, a self-replicating nanotechnology is used as a weapon.

Nanites (referred to more often as Nanomachines) are often referenced in Konami's "Metal Gear" series being used to enhance and regulate abilities and body functions.

In the Star Trek franchise TV shows nanites play an important plot device. Starting with "Evolution" in the third season of The Next Generation, Borg Nanoprobes perform the function of maintaining the Borg cybernetic systems, as well as repairing damage to the organic parts of a Borg. They generate new technology inside a Borg when needed, as well as protecting them from many forms of disease.

Nanites play a role in the video game Deus Ex, being the basis of the nano-augmentation technology, which gives augmented people superhuman abilities.

Nanites are also mentioned in the Arc of a Scythe book series by Neal Shusterman and are used to heal all nonfatal injuries, regulate bodily functions, and considerably lessen pain.

Nanites are also an integral part of the Stargate SG1 and Stargate Atlantis, where grey goo scenarios are portrayed.

Power source

At present, mostly (lead–acid) batteries are used as a power source. Many different types of batteries can be used as a power source for robots. They range from lead–acid batteries, which are safe and have relatively long shelf lives but are rather heavy compared to silver–cadmium batteries that are much smaller in volume and are currently much more expensive. Designing a battery-powered robot needs to take into account factors such as safety, cycle lifetime and weight. Generators, often some type of internal combustion engine, can also be used. However, such designs are often mechanically complex and need a fuel, require heat dissipation and are relatively heavy. A tether connecting the robot to a power supply would remove the power supply from the robot entirely. This has the advantage of saving weight and space by moving all power generation and storage components elsewhere. However, this design does come with the drawback of constantly having a cable connected to the robot, which can be difficult to manage. Potential power sources could be:

- pneumatic (compressed gases)
- Solar power (using the sun's energy and converting it into electrical power)
- hydraulics (liquids)
- flywheel energy storage
- organic garbage (through anaerobic digestion)
- nuclear
- A robotic leg powered by air muscles

Actuators are the "muscles" of a robot, the parts which convert stored energy into movement. By far the most popular actuators are electric motors that rotate a wheel or gear, and linear actuators that control industrial robots in factories. There are some recent advances in alternative types of actuators, powered by electricity, chemicals, or compressed air.

Electric motors

The vast majority of robots use electric motors, often brushed and brushless DC motors in portable robots or AC motors in industrial robots and CNC machines.

These motors are often preferred in systems with lighter loads, and where the predominant form of motion is rotational.

Linear actuators

Various types of linear actuators move in and out instead of by spinning, and often have quicker direction changes, particularly when very large forces are needed such as with industrial robotics. They are typically powered by compressed and oxidized air (pneumatic actuator) or an oil (hydraulic actuator) Linear actuators can also be powered by electricity which usually consists of a motor and a leadscrew. Another common type is a mechanical linear actuator that is turned by hand, such as a rack and pinion on a car.

Series elastic actuators

Series elastic actuation (SEA) relies on the idea of introducing intentional elasticity between the motor actuator and the load for robust force control. Due to the resultant lower reflected inertia, series elastic actuation improves safety when a robot interacts with the environment (e.g., humans or workpiece) or during collisions. Furthermore, it also provides energy efficiency and shock absorption (mechanical filtering) while reducing excessive wear on the transmission and other mechanical components. This approach has successfully been employed in various robots, particularly advanced manufacturing robots and walking humanoid robots.

The controller design of a series elastic actuator is most often performed within the passivity framework as it ensures the safety of interaction with unstructured environments. Despite its remarkable[315] stability robustness, this framework suffers from the stringent limitations imposed on the controller which may trade-off performance. The reader is referred to the following survey which summarizes the common controller architectures for SEA along with the corresponding sufficient passivity conditions. One recent study has derived

[315] "Nanofactory Collaboration". *Molecularassembler.com*.

the necessary and sufficient passivity conditions for one of the most common impedance control architectures, namely velocity-sourced SEA. This work is of particular importance as it drives the non-conservative passivity bounds in an SEA scheme for the first time which allows a larger selection of control gains.

Air muscles

Pneumatic artificial muscles also known as air muscles, are special tubes that expand (typically up to 42%) when air is forced inside them. They are used in some robot applications.

Muscle wire

Muscle wire, also known as shape memory alloy, Nitinol or Flexinol wire, is a material which contracts (under 5%) when electricity is applied. They have been used for some small robot applications.

Electroactive polymers

EAPs or EPAMs are a plastic material that can contract substantially (up to 380% activation strain) from electricity, and have been

Recent alternatives to DC motors are piezo motors or ultrasonic motors. These work on a fundamentally different principle, whereby tiny piezoceramic elements, vibrating many thousands of times per second, cause linear or rotary motion. There are different mechanisms of operation; one type uses the vibration of the piezo elements to step the motor in a circle or a straight line.[316] Another type uses the piezo elements to cause a nut to vibrate or to drive a screw. The advantages of these motors are nanometer resolution, speed, and available force for their size. These motors are already available commercially, and being used on some robots.

[316] *Cepko, Constance; Pear, Warren (2001). "Overview of the Retrovirus Transduction System". Current Protocols in Molecular Biology. 36: 9.9.1–9.9.16. Doi:10.1002/0471142727.mb0909s36. ISSN 1934-3639. PMID 18265289. S2CID 30240008.*

Elastic nanotubes

Elastic nanotubes are a promising artificial muscle technology in early-stage experimental development. The absence of defects in carbon nanotubes enables these filaments to deform elastically by several percent, with energy storage levels of perhaps 10 J/cm^3 for metal nanotubes. Human biceps could be replaced with an 8 mm diameter wire of this material. Such compact "muscle" might allow future robots to outrun and outjump humans.

Sensing

Sensors allow robots to receive information about a certain measurement of the environment, or internal components. This is essential for robots to perform their tasks, and act upon any changes in the environment to calculate the appropriate response. They are used for various forms of measurements, to give the robots warnings about safety or malfunctions, and to provide real-time information of the task it is performing.

Touch

Current robotic and prosthetic hands receive far less tactile information than the human hand. Recent research has developed a tactile sensor array that mimics the mechanical properties and touch receptors of human fingertips.[67][68] The sensor array is constructed as a rigid core surrounded by conductive fluid contained by an elastomeric skin. Electrodes are mounted on the surface of the rigid core and are connected to an impedance-measuring device within the core. When the artificial skin touches an object the fluid path around the electrodes is deformed, producing impedance changes that map the forces received from the object. The researchers expect that an important function of such artificial fingertips will be adjusting robotic grip on held objects.

Scientists from several European countries and Israel developed a prosthetic hand in 2009, called Smart Hand, which functions like a real one allowing patients to write with it, type on a keyboard, play piano and perform other fine movements. The prosthesis has sensors which enable the patient to sense real feeling in its fingertips.

Vision

Computer vision is the science and technology of machines that see. As a scientific discipline, computer vision is concerned with the theory behind artificial systems that extract information from images. The image data can take many forms, such as video sequences and views from cameras.

In most practical computer vision applications, the computers are pre-programmed to solve a particular task, but methods based on learning are now becoming increasingly common.

Computer vision systems rely on image sensors which detect electromagnetic radiation which is typically in the form of either visible light or infra-red light. The sensors are designed using solid-state physics. The process by which light propagates and reflects off surfaces is explained using optics. Sophisticated image sensors even require quantum mechanics to provide a complete understanding of the image formation process. Robots can also be equipped with multiple vision sensors to be better able to compute the sense of depth in the environment. Like human eyes, robots' "eyes" must also be able to focus on a particular area of interest, and also adjust to variations in light intensities.

There is a subfield within computer vision where artificial systems are designed to mimic the processing and behavior of biological system, at different levels of complexity. Also, some of the learning-based methods developed within computer vision have their background in biology.

Other

Other common forms of sensing in robotics use lidar, radar, and sonar. Lidar measures distance to a target by illuminating the target with laser light and measuring the reflected light with a sensor. Radar uses radio waves to determine the range, angle, or velocity of objects. Sonar uses sound propagation to navigate, communicate with or detect objects on or under the surface of the water.

A definition of robotic manipulation has been provided by Matt Mason as: "manipulation refers to an agent's control of its environment through selective contact”

Robots need to manipulate objects; pick up, modify, destroy, or otherwise have an effect. Thus, the functional end of a robot arm intended to make the effect (whether a hand, or tool) are often referred to as while the "arm" is referred to as a manipulator. Most robot arms have replaceable end-effectors, each allowing them to perform some small range of tasks. Some have a fixed manipulator that cannot be replaced, while a few have one very general-purpose manipulator, for example, a humanoid hand

Mechanical grippers

One of the most common types of end-effectors are "grippers". In its simplest manifestation, it consists of just two fingers that can open and close to pick up and let go of a range of small objects. Fingers can, for example, be made of a chain with a metal wire run through it. Hands that resemble and work more like a human hand include the Shadow Hand and the Robonaut hand. Hands that are of a mid-level complexity include the Delft hand. Mechanical grippers can come in various types, including friction and encompassing jaws. Friction jaws use all the force of the gripper to hold the object in place using friction. Encompassing jaws cradle the object in place, using less friction.

Suction end-effectors

Suction end-effectors, powered by vacuum generators, are very simple astrictive devices that can hold very large loads provided the prehension surface is smooth enough to ensure suction.

Pick and place robots for electronic components and for large objects like car windscreens, often use very simple vacuum end-effectors.

Suction is a highly used type of end-effector in industry, in part because the natural compliance of soft suction end-effectors can enable a robot to be more robust in the presence of imperfect robotic perception. As an example: consider the case of a robot vision system estimates the position of a water bottle, but has 1 centimeter of error. While this may cause a rigid mechanical gripper to puncture the water bottle, the soft suction end-effector may just bend slightly and conform to the shape of the water bottle surface.

General purpose effectors

Some advanced robots are beginning to use fully humanoid hands, like the Shadow Hand, MANUS, and the Schunk hand. These are highly dexterous manipulators, with as many as 20 degrees of freedom and hundreds of tactile sensors.

Locomotion

Rolling robots

For simplicity, most mobile robots have four wheels or a number of continuous tracks. Some researchers have tried to create more complex wheeled robots with only one or two wheels. These can have certain advantages such as greater efficiency and reduced parts, as well as allowing a robot to navigate in confined places that a four-wheeled robot would not be able to.

Two-wheeled balancing robots

Balancing robots generally use a gyroscope to detect how much a robot is falling and then drive the wheels proportionally in the same direction, to counterbalance the fall at hundreds of times per second, based on the dynamics of an inverted pendulum. Many different balancing robots have been designed. While the Segway is not commonly thought of as a robot, it can be thought of as a component of a robot, when used as such Segway refer to them as RMP (Robotic Mobility Platform). An example of this use has been as NASA's Robonaut that has been mounted on a Segway.

One-wheeled balancing robots

A one-wheeled balancing robot is an extension of a two-wheeled balancing robot so that it can move in any 2D direction using a round ball as its only wheel. Several one-wheeled balancing robots have been designed recently, such as Carnegie Mellon University's "Ballbot" that is the approximate height and width of a person, and Tohoku Gakuin University's "BallIP".Because of the long, thin shape and ability to maneuver in tight spaces, they have the potential to function better than other robots in environments with people.

Spherical orb robots

Several attempts have been made in robots that are completely inside a spherical ball, either by spinning a weight inside the ball, or by rotating the outer shells of the sphere. These have also been referred to as an orb bot or a ball bot.

Six-wheeled robots

Using six wheels instead of four wheels can give better traction or grip in outdoor terrain such as on rocky dirt or grass.

Tracked robots

Tank tracks provide even more traction than a six-wheeled robot. Tracked wheels behave as if they were made of hundreds of wheels, therefore are very common for outdoor and military robots, where the robot must drive on very rough terrain. However, they are difficult to use indoors such as on carpets and smooth floors. Examples include NASA's Urban Robot "Urbie".

Walking applied to robots

Walking is a difficult and dynamic problem to solve. Several robots have been made which can walk reliably on two legs, however, none have yet been made which are as robust as a human. There has been much study on human inspired walking, such as AMBER lab which was established in 2008 by the Mechanical Engineering Department at Texas A&M University. Many other robots have been built that walk on more than two legs, due to these robots being significantly easier to construct. Walking robots can be used for uneven terrains, which would provide better mobility and energy efficiency than other locomotion methods. Typically, robots on two legs can walk well on flat floors and can occasionally walk up stairs. None can walk over rocky, uneven terrain. Some of the methods which have been tried are:

ZMP technique

The zero-moment point (ZMP) is the algorithm used by robots such as Honda's ASIMO. The robot's onboard computer tries to keep the total inertial forces (the combination of Earth's gravity and the acceleration and deceleration of walking), exactly opposed by the floor reaction force (the force of the floor pushing back on the robot's foot). In this way, the two forces cancel out, leaving no moment (force causing the robot to rotate and fall over) However, this is not exactly how a human walks, and the difference is obvious to human observers, some of whom have pointed out that ASIMO walks as if it needs the lavatory. ASIMO's walking algorithm is not static, and some dynamic balancing is used (see below). However, it still requires a smooth surface to walk on.

Hopping

Several robots, built in the 1980s by Marc Raibert at the MIT Leg Laboratory, successfully demonstrated very dynamic walking. Initially, a robot with only one leg, and a very small foot could stay upright simply by hopping. The movement is the same as that of a person on a pogo stick. As the robot falls to one side, it would jump slightly in that direction, in order to catch itself.[1] Soon, the algorithm was generalised to two and four legs. A bipedal robot was demonstrated running and even performing somersaults. A quadruped was also demonstrated which could trot, run, pace, and bound. For a full list of these robots, see the MIT Leg Lab Robots page.

Dynamic balancing (controlled falling)

A more advanced way for a robot to walk is by using a dynamic balancing algorithm, which is potentially more robust than the Zero Moment Point technique, as it constantly monitors the robot's motion, and places the feet in order to maintain stability. This technique was recently demonstrated by Anybots' Dexter

Robot,[1] which is so stable, it can even jump.[1] Another example is the TU Delft Flame.

Passive dynamics

Perhaps the most promising approach utilizes passive dynamics where the momentum of swinging limbs is used for greater efficiency. It has been shown that totally unpowered humanoid mechanisms can walk down a gentle slope, using only gravity to propel themselves. Using this technique, a robot need only supply a small amount of motor power to walk along a flat surface or a little more to walk up a hill. This technique promises to make walking robots at least ten times more efficient than ZMP walkers, like ASIMO.

Other Methods Of Locomotion

Flying

A modern passenger airliner is essentially a flying robot, with two humans to manage it. The autopilot can control the plane for each stage of the journey, including take off, normal flight, and even landing. Other flying robots are uninhabited and are known as unmanned aerial vehicles (UAVs). They can be smaller and lighter without a human pilot on board, and fly into dangerous territory for military surveillance missions. Some can even fire on targets under command. UAVs are also being developed which can fire on targets automatically, without the need for a command from a human. Other flying robots include cruise missiles, the Entomopter, and the Epson micro helicopter robot. Robots such as the Air Penguin, Air Ray, and Air Jelly have lighter-than-air bodies, propelled by paddles, and guided by sonar.

Snaking

Two robot snakes. Left one has 64 motors (with 2 degrees of freedom per segment), the right one 10. Several snake robots have been successfully developed. Mimicking the way real snakes move, these robots can navigate very confined spaces, meaning they may one day be used to search for people trapped in collapsed buildings. The Japanese ACM-R5 snake robot can even navigate both on land and in water.

Skating

A small number of skating robots have been developed, one of which is a multi-mode walking and skating device. It has four legs, with unpowered wheels, which can either step or roll. Another robot, Plen, can use a miniature skateboard or roller-skates, and skate across a desktop.

Capuchin, a climbing robot

Climbing

Several different approaches have been used to develop robots that have the ability to climb vertical surfaces. One approach mimics the movements of a human climber on a wall with protrusions; adjusting the center of mass and moving each limb in turn to gain leverage. An example of this is Capuchin, built by Dr. Ruixiang Zhang at Stanford University, California. Another approach uses the specialized toe pad method of wall-climbing geckoes, which can run on smooth surfaces such as vertical glass. Examples of this approach include Wallbot and Stickybot.

China's Technology Daily reported on 15 November 2008, that Dr. Li Hiu Yeung and his research group of New Concept Aircraft (Zhuhai) Co., Ltd. had successfully developed a bionic gecko robot named "Speedy Freelander". According to Dr. Yeung, the gecko robot could rapidly climb up and down a variety of building walls, navigate through ground and wall fissures, and walk upside-down on the ceiling. It was also able to adapt to the surfaces of smooth glass, rough, sticky or dusty walls as well as various types of metallic materials. It could also identify and circumvent obstacles automatically. Its flexibility and speed were comparable to a natural gecko. A third approach is to mimic the motion of a snake climbing a pole.

Swimming (Piscine)[edit that when swimming some fish can achieve a propulsive efficiency greater than 90%.Furthermore, they can accelerate and maneuver far better than any man-made boat or submarine, and produce less noise and water disturbance. Therefore, many researchers studying underwater robots would like to copy this type of locomotion. Notable examples are the Essex University Computer Science Robotic Fish G9, and the Robot Tuna built by the Institute of Field Robotics, to analyze and mathematically model thunniform motion. The Aqua Penguin, designed and built by Festo of Germany, copies the streamlined shape and propulsion by front "flippers" of penguins. Festo have also built the Aqua Ray and Aqua Jelly, which emulate the locomotion of manta ray, and jellyfish, respectively.

In 2014 iSplash-II was developed by PhD student Richard James Clapham and Prof. Huosheng Hu at Essex University. It was the first robotic fish capable of outperforming real carangiform fish in terms of average maximum velocity (measured in body lengths/ second) and endurance, the duration that top speed is maintained. This build attained swimming speeds of 11.6BL/s (i.e., 3.7 m/s). The first build, iSplash-I (2014) was the first robotic platform to apply a full-body length carangiform swimming motion which was found to increase swimming speed by 27% over the traditional approach of a posterior confined waveform.

Sailing

Sailboat robots have also been developed in order to make measurements at the surface of the ocean. A typical sailboat robot is Vaimos built by IFREMER and ENSTA-Bretagne. Since the propulsion of sailboat robots uses the wind, the energy of the batteries is only used for the computer, for the communication and for the actuators (to tune the rudder and the sail). If the robot is equipped with solar panels, the robot could theoretically navigate forever. The two main competitions of sailboat robots are WRSC, which takes place every year in Europe, and Sailbot.

Environmental interaction and navigation

Though a significant percentage of robots in commission today are either human controlled or operate in a static environment, there is an increasing interest in robots that can operate autonomously in a dynamic environment. These robots require some combination of navigation hardware and software in order to traverse their environment. In particular, unforeseen events (e.g., people and other obstacles that are not stationary) can cause problems or collisions. Some highly advanced robots such as ASIMO and Meinü robot have particularly good robot navigation hardware and software. Also, self-controlled cars, Ernst Dickmanns' driverless car, and the entries in the DARPA Grand Challenge, are capable of sensing the environment well and subsequently making navigational decisions based on this information, including by a swarm of autonomous robots. Most of these robots employ a GPS navigation device with waypoints, along with radar, sometimes combined with other sensory data such as lidar, video cameras, and inertial guidance systems for better navigation between waypoints.

Human-robot interaction

The state of the art in sensory intelligence for robots will have to progress through several orders of magnitude if we want the robots working in our homes to go beyond vacuum-cleaning the floors. If robots are to work effectively in homes and other non-industrial environments, the way they are instructed to perform their jobs, and especially how they will be told to stop will be of critical importance. The people who interact with them may have little or no training in robotics, and so any interface will need to be extremely intuitive. Science fiction authors also typically assume that robots will eventually be capable of communicating with humans through speech, gestures, and facial expressions, rather than a command-line interface. Although speech would be the most natural way for the human to communicate, it is unnatural for the robot. It will probably be a long time before robots interact as naturally as the fictional C-3PO, or Data of Star Trek, Next Generation. Even though the current state of robotics cannot meet the standards of these robots from science-fiction, robotic media characters (e.g., Wall-E, R2-D2) can elicit audience sympathies that increase people's willingness to accept actual robots in the future. Acceptance of social robots is also likely to increase if people can meet a social robot under appropriate conditions. Studies have shown that interacting with a robot by looking at, touching, or even imagining interacting with the robot can reduce negative feelings that some people have about robots before interacting with them. However, if pre-existing negative sentiments are especially strong, interacting with a robot can increase those negative feelings towards robots.

Speech recognition

Interpreting the continuous flow of sounds coming from a human, in real time, is a difficult task for a computer, mostly because of the great variability of speech.[] The same word, spoken by the same person may sound different depending on local acoustics, volume, the previous word, whether or not the speaker has a cold, etc.. It becomes even harder when the speaker has a different accent. Nevertheless, great strides have been made in the field since Davis, Biddulph, and Balashek designed the first "voice input system" which recognized "ten digits spoken by a single user with 100% accuracy" in 1952. Currently, the best systems can recognize continuous, natural speech, up to 160 words per minute, with an accuracy of 95%.With the help of artificial intelligence, machines nowadays can use people's voice to identify their emotions such as satisfied or angry.

Robotic voice

Other hurdles exist when allowing the robot to use voice for interacting with humans. For social reasons, synthetic voice proves suboptimal as a communication medium, making it necessary to develop the emotional component of robotic voice through various techniques. An advantage of diphonic branching is the emotion that the robot is programmed to project, can be carried on the voice tape, or phoneme, already pre-programmed onto the voice media. One of the earliest examples is a teaching robot named Leachim developed in 1974 by Michael J. Freeman. Leachim was able to convert digital memory to rudimentary verbal speech on pre-recorded computer discs. It was programmed to teach students in The Bronx, New York.

Gestures

One can imagine, in the future, explaining to a robot chef how to make a pastry, or asking directions from a robot police officer. In both of these cases, making hand gestures would aid the verbal descriptions. In the first case, the robot would be recognizing gestures made by the human, and perhaps repeating them for confirmation. In the second case, the robot police officer would gesture to indicate "down the road, then turn right". It is likely that gestures will make up a part of the interaction between humans and robots. A great many systems have been developed to recognize human hand gestures.

Facial expression

Facial expressions can provide rapid feedback on the progress of a dialog between two humans, and soon may be able to do the same for humans and robots. Robotic faces have been constructed by Hanson Robotics using their elastic polymer called Frubber, allowing a large number of facial expressions due to the elasticity of the rubber facial coating and embedded subsurface motors (servos).[The coating and servos are built on a metal skull. A robot should know how to approach a human, judging by their facial expression and body language. Whether the person is happy, frightened, or crazy-looking affects the type of interaction expected of the robot. Likewise, robots like Kismet and the more recent addition, Nexican produce a range of facial expressions, allowing it to have meaningful social exchanges with humans.

Artificial emotions

Artificial emotions can also be generated, composed of a sequence of facial expressions or gestures. As can be seen from the movie Final Fantasy: The Spirits Within, the programming of these artificial emotions is complex and requires a large amount of human observation. To simplify this programming in the movie, presets were created together with a special software program. This decreased the amount of time needed to make the film. These presets could possibly be transferred for use in real-life robots. An example of a robot with artificial emotions is Robin the Robot developed by an Armenian IT company Expper Technologies, which uses AI-based peer-to-peer interaction. Its main task is achieving emotional well-being, i.e., overcome stress and anxiety. Robin was trained to analyze facial expressions and use his face to display his emotions given the context. The robot has been tested by kids in US clinics, and observations show that Robin increased the appetite and cheerfulness of children after meeting and talking.

Personality

Many of the robots of science fiction have a personality, something which may or may not be desirable in the commercial robots of the future. Nevertheless, researchers are trying to create robots which appear to have a personality: i.e., they use sounds, facial expressions, and body language to try to convey an internal state, which may be joy, sadness, or fear. One commercial example is Pleo, a toy robot dinosaur, which can exhibit several apparent emotions.

Social intelligence

The Socially Intelligent Machines Lab of the Georgia Institute of Technology researches new concepts of guided teaching interaction with robots. The aim of the projects is a social robot that learns task and goals from human demonstrations without prior knowledge of high-level concepts. These new concepts are grounded from low-level continuous sensor data through unsupervised learning, and task goals are subsequently learned using a Bayesian approach. These concepts can be used to transfer knowledge to future tasks, resulting in faster learning of those tasks. The results are demonstrated by the robot Curi who can scoop some pasta from a pot onto a plate and serve the sauce on top.

The mechanical structure of a robot must be controlled to perform tasks. The control of a robot involves three distinct phases perception, processing, and action (robotic paradigms). Sensors give information about the environment or the robot itself (e.g., the position of its joints or its end effector). This information is then processed to be stored or transmitted and to calculate the appropriate signals to the actuators (motors), which move the mechanical structure to achieve the required co-ordinated motion or force actions.

The processing phase can range in complexity. At a reactive level, it may translate raw sensor information directly into actuator commands (e.g., firing motor power electronic gates based directly upon encoder feedback signals to achieve the required torque/velocity of the shaft). Sensor fusion and internal models may first be used to estimate parameters of interest (e.g., the position of the robot's gripper) from noisy sensor data. An immediate task (such as moving the gripper in a certain direction until an object is detected with a proximity sensor) is sometimes inferred from these estimates. Techniques from control theory are generally used to convert the higher-level tasks into individual commands that drive the actuators, most often using kinematic and dynamic models of the mechanical structure.

At longer time scales or with more sophisticated tasks, the robot may need to build and reason with a "cognitive" model. Cognitive models try to represent the robot, the world, and how the two interact. Pattern recognition and computer vision can be used to track objects. Mapping techniques can be used to build maps of the world. Finally, motion planning and other artificial intelligence techniques may be used to figure out how to act. For example, a planner may figure out how to achieve a task without hitting obstacles, falling over, etc.

Modern commercial robotic control systems are highly complex, integrate multiple sensors and effectors, have many interacting degrees-of-freedom (DOF) and require operator interfaces, programming tools and real-time capabilities. They are oftentimes interconnected to wider communication networks and in many cases are now both IoT-enabled and mobile. Progress towards open architecture, layered, user-friendly and 'intelligent' sensor-based interconnected robots has emerged from earlier concepts related to Flexible Manufacturing Systems (FMS), and several 'open or 'hybrid' reference architectures exist which assist developers of robot control software and hardware to move beyond traditional, earlier notions of 'closed' robot control systems have been proposed. Open architecture controllers are said to be better able to meet the growing requirements of a wide range of robot users, including system developers, end users and research scientists, and are better positioned to deliver the advanced robotic concepts related to Industry . In addition to utilizing many established features of robot controllers, such as position, velocity and force control of end effectors, they also enable IoT interconnection and the implementation of more advanced sensor fusion and control techniques, including adaptive control, Fuzzy control and Artificial Neural Network (ANN)-based control. When implemented in real-time, such techniques can potentially improve the stability and performance of robots operating in unknown or uncertain environments by enabling the control systems to learn and adapt to environmental changes. There are several examples of reference architectures for robot controllers, and also examples of successful implementations of actual robot controllers developed from them. One example of a generic reference architecture and associated interconnected, open-architecture robot and controller implementation was developed by Michael Short and colleagues at the University of Sunderland in the UK in 2000 (pictured right). The robot was used in a number of research and development studies, including prototype implementation of novel advanced and intelligent control and environment mapping methods in real-time.

CHAPTER ELEVEN

Remote-Controlled Systems

The Brennan Torpedo, One Of The Earliest 'Guided Missiles'

Remotely operated vehicles were demonstrated in the late 19th century in the form of several types of remotely controlled torpedoes. The early 1870s saw remotely controlled torpedoes by John Ericsson (pneumatic), John Louis Lay (electric wire guided), and Victor von Scheliha (electric wire guided).[317]

The Brennan torpedo, invented by Louis Brennan in 1877, was powered by two contra-rotating propellers that were spun by rapidly pulling out wires from drums wound inside the torpedo. Differential speed on the wires connected to the shore station allowed the torpedo to be guided to its target, making it "the world's first practical guided missile". In 1897 the British inventor Ernest Wilson was granted a patent for a torpedo remotely controlled by "Hertzian" (radio) waves and in 1898 Nikola Tesla publicly demonstrated a wireless-controlled torpedo that he hoped to sell to the US Navy.

In 1903, the Spanish engineer Leonardo Torres y Quevedo demonstrated a radio control system called "Telekino", which he wanted to use to control an airship of his own design. Unlike the previous systems, which carried out actions of the 'on/off' type, Torres device was able to memorize the signals received to execute the operations on its own and could carry out to 19 different orders.

Archibald Low, known as the "father of radio guidance systems" for his pioneering work on guided rockets and planes during the First World War. In 1917, he

[317] http://en.wikipedia.org/wiki/Robot# cite note- Edwyn grey 39

demonstrated a remote-controlled aircraft to the Royal Flying Corps and in the same year built the first wire-guided rocket.

EARLY HUMANOID ROBOT

In 1928, one of the first humanoid robots, Eric, was exhibited at the annual exhibition of the Model Engineers Society in London, where it delivered a speech. Invented by W. H. Richards, the robot's frame consisted of an aluminium body of armour with eleven electromagnets and one motor powered by a twelve-volt power source. The robot could move its hands and head and could be controlled through remote control or voice control.[318] Both Eric and his "brother" George toured the world. Westinghouse Electric Corporation built Televox in 1926; it was a cardboard cut out connected to various devices which users could turn on and off. In 1939, the humanoid robot known as Elektro was debuted at the 1939 New York World's Fair. Seven feet tall (2.1 m) and weighing 265 pounds (120.2 kg), it could walk by voice command, speak about 700 words (using a 78-rpm record player), smoke cigarettes, blow up balloons, and move its head and arms. The body consisted of a steel gear, cam and motor skeleton covered by an aluminum skin. In 1928, Japan's first robot, Gakutensoku, was designed and constructed by biologist Makoto Nishimura.

MODERN AUTONOMOUS ROBOTS

The first electronic autonomous robots with complex behaviour were created by William Grey Walter of the Burden Neurological Institute at Bristol, England in 1948 and 1949. He wanted to prove that rich connections between a small number of brain cells could give rise to very complex behaviors – essentially that the secret of how the brain worked lay in how it was wired up. His first robots, named Elmer and Elsie, were constructed between 1948 and 1949 and were often described as tortoises due to their shape and slow rate of movement. The three-

[318] http://en.wikipedia.org/wiki/Robot# cite note- 51

wheeled tortoise robots were capable of phototaxis, by which they could find their way to a recharging station when they ran low on battery power.

Walter stressed the importance of using purely analogue electronics to simulate brain processes at a time when his contemporaries such as Alan Turing and John von Neumann were all turning towards a view of mental processes in terms of digital computation. His work inspired subsequent generations of robotics researchers such as Rodney Brooks, Hans Moravec and Mark Tilden. Modern incarnations of Walter's turtles may be found in the form of BEAM robotics.[319]

The first digitally operated and programmable robot was invented by George Devol in 1954 and was ultimately called the Unimate. This ultimately laid the foundations of the modern robotics sindustry. Devol sold the first Unimate to General Motors in 1960, and it was installed in 1961 in a plant in Trenton, New Jersey to lift hot pieces of metal from a die casting machine and stack them. Devol's patent for the first digitally operated programmable robotic arm represents the foundation of the modern robotics industry.[320]

The first palletizing robot was introduced in 1963 by the Fuji Yusoki Kogyo Company. In 1973, a robot with six electromechanically driven axes was patented by KUKA robotics in Germany, and the programmable universal manipulation arm was invented by Victor Scheinman in 1976, and the design was sold to Unimation.

Commercial and industrial robots are now in widespread use performing jobs more cheaply or with greater accuracy and reliability than humans. They are also employed for jobs which are too dirty, dangerous or dull to be suitable for humans. Robots are widely used in manufacturing, assembly and packing, transport, earth and space exploration, surgery, weaponry, laboratory research, and mass production of consumer and industrial goods.

[319] ibid

[320] http://en.wikipedia.org/wiki/Robot# cite note- 58

Various techniques have emerged to develop the science of robotics and robots. One method is evolutionary robotics, in which a number of differing robots are submitted to tests. Those which perform best are used as a model to create a subsequent "generation" of robots. Another method is developmental robotics, which tracks changes and development within a single robot in the areas of problem-solving and other functions. Another new type of robot is just recently introduced which acts both as a smartphone and robot and is named RoboHon.

As robots become more advanced, eventually there may be a standard computer operating system designed mainly for robots. Robot Operating System is an open-source set of programs being developed at Stanford University, the Massachusetts Institute of Technology and the Technical University of Munich, Germany, among others. ROS provides ways to program a robot's navigation and limbs regardless of the specific hardware involved. It also provides high-level commands for items like image recognition and even opening doors. When ROS boots up on a robot's computer, it would obtain data on attributes such as the length and movement of robots' limbs. It would relay this data to higher-level algorithms. Microsoft is also developing a "Windows for robots" system with its Robotics Developer Studio, which has been available since 2007.

Japan hopes to have full-scale commercialization of service robots by 2025. Much technological research in Japan is led by Japanese government agencies, particularly the Trade Ministry.

Many future applications of robotics seem obvious to people, even though they are well beyond the capabilities of robots available at the time of the prediction. As early as 1982 people were confident that someday robots would:

1. Clean parts by removing molding flash

2. Spray paint automobiles with absolutely no human presence 3. Pack things in boxes—for example, orient and nest chocolate candies in candy boxes

4. Make electrical cable harness

5. Load trucks with boxes—a packing problem

6. Handle soft goods, such as garments and shoes

7. Shear sheep

8. prosthesis

9. Cook fast food and work in other service industries

10. Household robot.

Generally, such predictions are overly optimistic in timescale.

New Functionalities And Prototypes

In 2008, Caterpillar Inc. developed a dump truck which can drive itself without any human operator.[321]Many analysts believe that self-driving trucks may eventually revolutionize logistics, By 2014, Caterpillar had a self-driving dump truck which is expected to greatly change the process of mining. In 2015, these Caterpillar trucks were actively used in mining operations in Australia by the mining company Rio Tinto Coal Australia Some analysts believe that within the next few decades, most trucks will be self-driving.[322]

A literate or 'reading robot named Marge has intelligence that comes from software. She can read newspapers, find and correct misspelled words, learn about banks like Barclays, and understand that some restaurants are better places to eat than others.[77]

Baxter is a new robot introduced in 2012 which learns by guidance. A worker could teach Baxter how to perform a task by moving its hands in the desired motion and having Baxter memorize them. Extra dials, buttons, and controls are available on Baxter's arm for more precision and features. Any regular worker could program Baxter and it only takes a matter of minutes, unlike usual industrial robots that take extensive programs and coding to be used. This means Baxter needs no

[321] http://en.wikipedia.org/wiki/Robot# cite note- 70

[322] http://en.wikipedia.org/wiki/Robot# cite note- 76

programming to operate. No software engineers are needed. This also means Baxter can be taught to perform multiple, more complicated tasks. Sawyer was added in 2015 for smaller, more precise tasks.

Prototype cooking robots have been developed and could be programmed for autonomous, dynamic and adjustable preparation of discrete meals.

Mobile Robot

Mobile robots[323] have the capability to move around in their environment and are not fixed to one physical location. An example of a mobile robot that is in common use today is the automated guided vehicle or automatic guided vehicle (AGV). An AGV is a mobile robot that follows markers or wires in the floor, or uses vision or lasers.[324]AGVs are discussed later in this article.

Mobile robots are also found in industry, military and security environments hey also appear as consumer products, for entertainment or to perform certain tasks like vacuum cleaning. Mobile robots are the focus of a great deal of current research and almost every major university has one or more labs that focus on mobile robot research.

Mobile robots are usually used in tightly controlled environments such as on assembly lines because they have difficulty responding to unexpected interference. Because of this most humans rarely encounter robots. However, domestic robots for cleaning and maintenance are increasingly common in and around homes in developed countries. Robots can also be found in military applications.[325]

Industrial robots (manipulating)

A Pick And Place Robot In A Actory

323 http://en.wikipedia.org/wiki/Robot# cite note- 85

324 http://en.wikipedia.org/wiki/Robot# cite note- seegrid 86

325 http://en.wikipedia.org/wiki/Robot# cite note- 89

Industrial robots usually consist of a jointed arm (multi-linked manipulator) and an end effector that is attached to a fixed surface. One of the most common types of end effect or is a gripper assembly.

The International Organization for Standardization gives a definition of a manipulating industrial robot in ISO 8373:

"An automatically controlled, reprogrammable, multipurpose, manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications."[326]

This definition is used by the International Federation of Robotics, the European Robotics Research Network (EURON) and many national standards committees.[327]

Service Robot

Most commonly industrial robots are fixed robotic arms and manipulators used primarily for production and distribution of goods. The term "service robot" is less well-defined. The International Federation of Robotics has proposed a tentative definition, "A service robot is a robot which operates semi- or fully autonomously to perform services useful to the well-being of humans and equipment, excluding manufacturing operations."]

Educational (Interactive) Robots

Robots are used as educational assistants to teachers. From the 1980s, robots such as turtles were used in schools and programmed using the Logo language.

There are robot kits like Lego Mindstorms, BIOLOID, OLLO from ROBOTIS, or BotBrain Educational Robots can help children to learn about mathematics, physics, programming, and electronics. Robotics have also been introduced into the

[326] http://en.wikipedia.org/wiki/Robot# cite note- 90

[327] http://en.wikipedia.org/wiki/Robot# cite note- 91

lives of elementary and high school students in the form of robot competitions with the company FIRST (For Inspiration and Recognition of Science and Technology). The organization is the foundation for the FIRST Robotics Competition, FIRST Tech Challenge, FIRST Lego League Challenge and FIRST Lego League Explore competitions.

There have also been robots such as the teaching computer, Leachim (1974).[328]Leachim was an early example of speech synthesis using the using the Diphone synthesis method. 2-XL (1976) was a robot shaped game / teaching toy based on branching between audible tracks on an 8-track tape player, both invented by Michael J. Freeman. Later, the 8-track was upgraded to tape cassettes and then to digital.

Modular Robot

Modular robots are a new breed of robots that are designed to increase the use of robots by modularizing their architecture.[329] The functionality and effectiveness of a modular robot is easier to increase compared to conventional robots. These robots are composed of a single type of identical, several different identical module types, or similarly shaped modules, which vary in size. Their architectural structure allows hyper-redundancy for modular robots, as they can be designed with more than 8 degrees of freedom (DOF). Creating the programming, inverse kinematics and dynamics for modular robots is more complex than with traditional robots. Modular robots may be composed of L-shaped modules, cubic modules, and U and H-shaped modules. ANAT technology, an early modular robotic technology patented by Robotics Design Inc., allows the creation of modular robots from U and H shaped modules that connect in a chain, and are used to form heterogeneous and homogenous modular robot systems. These "ANAT robots" can be designed with "n" DOF as each module is a complete motorized robotic system that folds relatively to the modules connected before and after it in its chain, and therefore a single module allows one degree of freedom. The more modules that are connected

[328] http://en.wikipedia.org/wiki/Robot# cite note- 95

[329] http://en.wikipedia.org/wiki/Robot# cite note- 97

to one another, the more degrees of freedom it will have. L-shaped modules can also be designed in a chain, and must become increasingly smaller as the size of the chain increases, as payloads attached to the end of the chain place a greater strain on modules that are further from the base. ANAT H-shaped modules do not suffer from this problem, as their design allows a modular robot to distribute pressure and impacts evenly amongst other attached modules, and therefore payload-carrying capacity does not decrease as the length of the arm increases. Modular robots can be manually or self-reconfigured to form a different robot, that may perform different applications. Because modular robots of the same architecture type are composed of modules that compose different modular robots, a snake-arm robot can combine with another to form a dual or quadra-arm robot, or can split into several mobile robots, and mobile robots can split into multiple smaller ones, or combine with others into a larger or different one. This allows a single modular robot the ability to be fully specialized in a single task, as well as the capacity to be specialized to perform multiple different tasks.

Modular robotic technology is currently being applied in hybrid transportation,[330]industrial automation duct cleaning and handling. Many research centres and universities have also studied this technology, and have developed prototypes.

Collaborative Robots

A collaborative robot or cobot is a robot that can safely and effectively interact with human workers while performing simple industrial tasks. However, end-effectors and other environmental conditions may create hazards, and as such risk assessments should be done before using any industrial motion-control application.

The collaborative robots most widely used in industries today are manufactured by Universal Robots in Denmark.

Rethink Robotics founded by Rodney Brooks, previously with iRobot introduced Baxter in September 2012; as an industrial robot designed to safely

[330] http://en.wikipedia.org/wiki/Robot# cite note- Modular flying car 98

interact with neighbouring human workers, and be programmable for performing simple tasks. Baxters stop if they detect a human in the way of their robotic arms and have prominent off switches. Intended for sale to small businesses, they are promoted as the robotic analogue of the personal computer. As of May 2014, 190 companies in the US have bought Baxters and they are being used commercially in the UK.

Robots In Society

Roughly half of all the robots in the world are in Asia, 32% in Europe, and 16% in North America, 1% in Australasia and 1% in Africa.[331] 40% of all the robots in the world are in Japan[332] making Japan the country with the highest number of robots.

An android, or robot designed to resemble a human, can appear comforting to some people and disturbing to others

As robots have become more advanced and sophisticated, experts and academics have increasingly explored the questions of what ethics might govern robots' behavior, and whether robots might be able to claim any kind of social, cultural, ethical or legal rights. One scientific team has said that it was possible that a robot brain would exist by 2019.Others predict robot intelligence breakthroughs by 2050.Recent advances have made robotic behavior more sophisticated. The social impact of intelligent robots is subject of a 2010 documentary film called Plug & Pray.

Vernor Vinge has suggested that a moment may come when computers and robots are smarter than humans. He calls this "Singularity". He suggests that it may be somewhat or possibly very dangerous for humans. This is discussed by a philosophy called Singularitarianism.

In 2009, experts attended a conference hosted by the Association for the Advancement of Artificial Intelligence (AAAI) to discuss whether computers and

[331] http://en.wikipedia.org/wiki/Robot# cite note- 77
[332] http://en.wikipedia.org/wiki/Robot# cite note- 108

robots might be able to acquire any autonomy, and how much these abilities might pose a threat or hazard. They noted that some robots have acquired various forms of semi-autonomy, including being able to find power sources on their own and being able to independently choose targets to attack with weapons. They also noted that some computer viruses can evade elimination and have achieved "cockroach intelligence." They noted that self-awareness as depicted in science-fiction is probably unlikely, but that there were other potential hazards and pitfalls. Various media sources and scientific groups have noted separate trends in differing areas which might together result in greater robotic functionalities and autonomy, and which pose some inherent concerns.[333]

MILITARY ROBOTS

Some experts and academics have questioned the use of robots for military combat, especially when such robots are given some degree of autonomous functions. There are also concerns about technology which might allow some armed robots to be controlled mainly by other robots.[334]The US Navy has funded a report which indicates that, as military robots become more complex, there should be greater attention to implications of their ability to make autonomous decisions.[335]One researcher states that autonomous robots might be more humane, as they could make decisions more effectively. However, other experts question this.

One robot in particular, the EATR, has generated public concerns over its fuel source, as it can continually refuel itself using organic substances. Although the engine for the EATR is designed to run on biomass and vegetation specifically selected by its sensors, which it can find on battlefields or other local environments, the project has stated that chicken fat can also be used.

Manuel De Landa has noted that "smart missiles" and autonomous bombs equipped with artificial perception can be considered robots, as they make some of their decisions autonomously. He believes this represents an important and

[333] http://en.wikipedia.org/wiki/Robot# cite note- 120

[334] http://en.wikipedia.org/wiki/Robot# cite note- 123

[335] http://en.wikipedia.org/wiki/Robot# cite note- 125

dangerous trend in which humans are handing over important decisions to machines

Robotic Age And Unemployment

For centuries, people have predicted that machines would make workers obsolete and increase unemployment, although the causes of unemployment are usually thought to be due to social policy.[336]

A recent example of human replacement involves Taiwanese technology company Foxconn who, in July 2011, announced a three-year plan to replace workers with more robots. At present the company uses ten thousand robots but will increase them to a million robots over a three-year period.

Lawyers have speculated that an increased prevalence of robots in the workplace could lead to the need to improve redundancy laws.

Kevin J. Delaney said "Robots are taking human jobs. But Bill Gates believes that governments should tax companies' use of them, as a way to at least temporarily slow the spread of automation and to fund other types of employment. "The robot tax would also help pay a guaranteed living wage to the displaced workers.

The World Bank's World Development Report 2019 puts forth evidence showing that while automation displaces workers, technological innovation creates more new industries and jobs on balance.[337]

CONTEMPORARY USES

At present, there are two main types of robots, based on their use: general-purpose autonomous robots and dedicated robots.

Robots can be classified by their specificity of purpose. A robot might be designed to perform one particular task extremely well, or a range of tasks less well. All robots

[336] http://en.wikipedia.org/wiki/Robot# cite note- 132

[337]http://en.wikipedia.org/wiki/Robot# cite note- 36

by their nature can be re-programmed to behave differently, but some are limited by their physical form. For example, a factory robot arm can perform jobs such as cutting, welding, gluing, or acting as a fairground ride, while a pick-and-place robot can only populate printed circuit boards.

General-Purpose Autonomous Robots

General-purpose autonomous robots can perform a variety of functions independently. General-purpose autonomous robots typically can navigate independently in known spaces, handle their own re-charging needs, interface with electronic doors and elevators and perform other basic tasks. Like computers, general-purpose robots can link with networks, software and accessories that increase their usefulness. They may recognize people or objects, talk, provide companionship, monitor environmental quality, respond to alarms, pick up supplies and perform other useful tasks. General-purpose robots may perform a variety of functions simultaneously or they may take on different roles at different times of day. Some such robots try to mimic human beings and may even resemble people in appearance; this type of robot is called a humanoid robot. Humanoid robots are still in a very limited stage, as no humanoid robot can, as of yet, actually navigate around a room that it has never been in. Thus, humanoid robots are really quite limited, despite their intelligent behaviors in their well-known environments for example Factory robots Car production

Over the last three decades, automobile factories have become dominated by robots. A typical factory contains hundreds of industrial robots working on fully automated production lines, with one robot for every ten human workers. On an automated production line, a vehicle chassis on a conveyor is welded, glued, painted and finally assembled at a sequence of robot stations.

Packaging

Industrial robots are also used extensively for palletizing and packaging of manufactured goods, for example for rapidly taking drink cartons from the end of a conveyor belt and placing them into boxes, or for loading and unloading machining canters.

Electronics

Mass-produced printed circuit boards (PCBs) are almost exclusively manufactured by pick-and-place robots, typically with SCARA manipulators, which remove tiny electronic components from strips or trays, and place them on to PCBs with great accuracy. Such robots can place hundreds of thousands of components per hour, far out-performing a human in speed, accuracy, and reliability.

Automated guided vehicles (AGVs)

Mobile robots, following markers or wires in the floor, or using vision or lasers, are used to transport goods around large facilities, such as warehouses, container ports, or hospitals.

Early AGV-style robots

Limited to tasks that could be accurately defined and had to be performed the same way every time. Very little feedback or intelligence was required, and the robots needed only the most basic exteroceptors (sensors). The limitations of these AGVs are that their paths are not easily altered and they cannot alter their paths if obstacles block them. If one AGV breaks down, it may stop the entire operation.

Interim AGV technologies

Developed to deploy triangulation from beacons or bar code grids for scanning on the floor or ceiling. In most factories, triangulation systems tend to require moderate to high maintenance, such as daily cleaning of all beacons or bar codes. Also, if a tall pallet or large vehicle blocks beacons or a bar code is marred, AGVs may become lost. Often such AGVs are designed to be used in human-free environments.

Intelligent AGVs (i-AGVs)

Such as Smart Loader, SpeciMinder, ADAM, Tug Eskorta and MT 400 with Motivity are designed for people-friendly workspaces. They navigate by recognizing natural features. 3D scanners or other means of sensing the environment in two or three dimensions help to eliminate cumulative errors in deadreckoning calculations of the AGV's current position. Some AGVs can create maps of their environment using scanning lasers with simultaneous localization and mapping (SLAM) and use those maps to navigate in real time with other path planning and obstacle avoidance algorithms. They are able to operate in complex environments and perform non-repetitive and non-sequential tasks such as transporting photomasks in a semiconductor lab, specimens in hospitals and goods in warehouses. For dynamic areas, such as warehouses full of pallets, AGVs require additional strategies using three-dimensional sensors such as time-of-flight or stereovision cameras.

Dirty, dangerous, dull, or inaccessible tasks

There are many jobs that humans would rather leave to robots. The job may be boring, such as domestic cleaning or sports field line marking, or dangerous, such as exploring inside a volcano. Other jobs are physically inaccessible, such as exploring another planet,[338] cleaning the inside of a long pipe, or performing laparoscopic surgery.

Space probes

Almost every unmanned space probe ever launched was a robot.[149][150] Some were launched in the 1960s with very limited abilities, but their ability to fly and land (in the case of Luna 9) is an indication of their status as a robot. This includes the Voyager probes and the Galileo probes, among others.

Telerobots

A U.S. Marine Corps technician prepares to use a telerobot to detonate a buried improvised explosive device near Camp Fallujah, Iraq.

Teleoperated robots, or telerobots, are devices remotely operated from a distance by a human operator rather than following a predetermined sequence of movements, but which has semi-autonomous behaviour. They are used when a human cannot be present on site to perform a job because it is dangerous, far away, or inaccessible.

[338] http://en.wikipedia.org/wiki/Robot# cite note- 77

The robot may be in another room or another country, or may be on a very different scale to the operator. For instance, a laparoscopic surgery robot allows the surgeon to work inside a human patient on a relatively small scale compared to open surgery, significantly shortening recovery time. They can also be used to avoid exposing workers to the hazardous and tight spaces such as in duct cleaning. When disabling a bomb, the operator sends a small robot to disable it. Several authors have been using a device called the Long pen to sign books remotely eleoperated robot aircraft, like the Predator Unmanned Aerial Vehicle, are increasingly being used by the military. These pilotless drones can search terrain and fire on targets. Hundreds of robots such as iRobot's Packbot and the Foster-Miller TALON are being used in Iraq and Afghanistan by the U.S. military to defuse roadside bombs or improvised explosive devices (IEDs) in an activity known as explosive ordnance disposal (EOD).[154]

Automated fruit harvesting machines

Robots are used to automate picking fruit on orchards at a cost lower than that of human pickers.

Domestic robots

The Roomba domestic vacuum cleaner robot does a single, menial job

Domestic robots are simple robots dedicated to a single task work in home use. They are used in simple but often disliked jobs, such as vacuum cleaning, floor washing, and lawn mowing. An example of a domestic robot is a Roomba.

Military robots

Military robots include the SWORDS robot which is currently used in ground-based combat. It can use a variety of weapons and there is some discussion of giving it some degree of autonomy in battleground situations.

Unmanned combat air vehicles (UCAVs), which are an upgraded form of UAVs, can do a wide variety of missions, including combat. UCAVs are being designed such as the BAE Systems Mantis which would have the ability to fly themselves, to pick their own course and target, and to make most decisions on their own. The BAE Taranis is a UCAV built by Great Britain which can fly across continents without a pilot and has new means to avoid detection.[339] Flight trials are expected to begin in 2011.[340]

The AAAI has studied this topic in depth and its president has commissioned a study to look at this issue.

Some have suggested a need to build "Friendly AI", meaning that the advances which are already occurring with AI should also include an effort to make AI intrinsically friendly and humane, Several such measures reportedly already exist, with robot-heavy countries such as Japan and South Korea having begun to pass regulations requiring robots to be equipped with safety systems, and possibly sets of 'laws' akin to Asimov's Robotics. An official report was issued in 2009 by the Japanese government's Robot Industry Policy Committee. Chinese officials and researchers have issued a report suggesting a set of ethical rules, and a set of new legal guidelines referred to as "Robot Legal Studies. Some concern has been expressed over a possible occurrence of robots telling apparent falsehoods.

Mining robots

Mining robots are designed to solve a number of problems currently facing the mining industry, including skills shortages, improving productivity from declining ore grades, and achieving environmental targets. Due to the hazardous nature of mining, in particular underground mining, the prevalence of autonomous, semi-autonomous, and tele-operated robots has greatly increased in recent times. A number of vehicle manufacturers provide autonomous trains, trucks and loaders that will load material, transport it on the mine site to its destination, and unload without requiring human intervention. One of the world's largest mining corporations, Rio Tinto, has recently expanded its autonomous truck fleet to the world's largest, consisting of 150 autonomous Komatsu trucks, operating

[339] http://en.wikipedia.org/wiki/Robot# cite note- 159

[340] http://en.wikipedia.org/wiki/Robot# cite note- 160

in Western Australia. Similarly, BHP has announced the expansion of its autonomous drill fleet to the world's largest, 21 autonomous Atlas Copco drills.

Drilling, longwall and rock breaking machines are now also available as autonomous robots.[171] The Atlas Copco Rig Control System can autonomously execute a drilling plan on a drilling rig, moving the rig into position using GPS, set up the drill rig and drill down to specified depths.[341] Similarly, the Transmin Rocklogic system can automatically plan a path to position a rock breaker at a selected destination. These systems greatly enhance the safety and efficiency of mining operations.

Healthcare

Robots in healthcare have two main functions. Those which assist an individual, such as a sufferer of a disease like Multiple Sclerosis, and those which aid in the overall systems such as pharmacies and hospitals.

Robots used in home automation have developed over time from simple basic robotic assistants, such as the Handy 1, through to semi-autonomous robots, such as FRIEND which can assist the elderly and disabled with common tasks.

The population is aging in many countries, especially Japan, meaning that there are increasing numbers of elderly people to care for, but relatively fewer young people to care for them. Humans make the best carers, but where they are unavailable, robots are gradually being introduced.

FRIEND is a semi-autonomous robot designed to support disabled and elderly people in their daily life activities, like preparing and serving a meal. FRIEND make it possible for patients who are paraplegic, have muscle diseases or serious paralysis (due to strokes etc.), to perform tasks without help from other people like therapists or nursing staff.

Pharmacies

[341] http://en.wikipedia.org/wiki/Robot# cite note- 172

Script Pro manufactures a robot designed to help pharmacies fill prescriptions that consist of oral solids or medications in pill form. The pharmacist or pharmacy technician enters the prescription information into its information system. The system, upon determining whether or not the drug is in the robot, will send the information to the robot for filling. The robot has 3 different size vials to fill determined by the size of the pill. The robot technician, user, or pharmacist determines the needed size of the vial based on the tablet when the robot is stocked. Once the vial is filled it is brought up to a conveyor belt that delivers it to a holder that spins the vial and attaches the patient label. Afterwards it is set on another conveyor that delivers the patient's medication vial to a slot labeled with the patient's name on an LED read out. The pharmacist or technician then checks the contents of the vial to ensure it's the correct drug for the correct patient and then seals the vials and sends it out front to be picked up.

McKesson's Robot RX is another healthcare robotics product that helps pharmacies dispense thousands of medications daily with little or no errors.[342] The robot can be ten feet wide and thirty feet long and can hold hundreds of different kinds of medications and thousands of doses. The pharmacy saves many resources like staff members that are otherwise unavailable in a resource scarce industry. It uses an electromechanical head coupled with a pneumatic system to capture each dose and deliver it to either its stocked or dispensed location. The head moves along a single axis while it rotates 180 degrees to pull the medications. During this process it uses barcode technology to verify it's pulling the correct drug. It then delivers the drug to a patient specific bin on a conveyor belt. Once the bin is filled with all of the drugs that a particular patient needs and that the robot stocks, the bin is then released and returned out on the conveyor belt to a technician waiting to load it into a cart for delivery to the floor.

Research robots

While most robots today are installed in factories or homes, performing labour or lifesaving jobs, many new types of robots are being developed in laboratories around the world. Much of the research in robotics focuses not on

[342] http://en.wikipedia.org/wiki/Robot# cite note- 179

specific industrial tasks, but on investigations into new types of robots, alternative ways to think about or design robots, and new ways to manufacture them. It is expected that these new types of robots will be able to solve real world problems when they are finally realized.

Bionic and biomimetic robots

One approach to designing robots is to base them on animals. Bionic Kangaroo was designed and engineered by studying and applying the physiology and methods of locomotion of a kangaroo.

Nanorobots

Nanorobotics is the emerging technology field of creating machines or robots whose components are at or close to the microscopic scale of a nanometer (10^{-9} meters). Also known as "nanobots" or "nanites", they would be constructed from molecular machines. So far, researchers have mostly produced only parts of these complex systems, such as bearings, sensors, and synthetic molecular motors, but functioning robots have also been made such as the entrants to the Nanobot Robocup contest. Researchers also hope to be able to create entire robots as small as viruses or bacteria, which could perform tasks on a tiny scale. Possible applications include micro surgery (on the level of individual cells), utility fog, manufacturing, weaponry and cleaning. Some people have suggested that if there were nanobots which could reproduce, the earth would turn into "grey goo", while others argue that this hypothetical outcome is nonsense.

Reconfigurable robots

A few researchers have investigated the possibility of creating robots which can alter their physical form to suit a particular task, like the fictional T-1000. Real robots are nowhere near that sophisticated however, and mostly consist of a small number of cube shaped units, which can move relative to their neighbours. Algorithms have been designed in case any such robots become a reality.

Robotic, mobile laboratory operators

In July 2020 scientists reported the development of a mobile robot chemist and demonstrate that it can assist in experimental searches. According to the scientists their strategy was automating the researcher rather than the instruments – freeing up time for the human researchers to think creatively – and could identify photocatalyst mixtures for hydrogen production from water that were six times more active than initial formulations. The modular robot can operate laboratory instruments, work nearly around the clock, and autonomously make decisions on his next actions depending on experimental results.

Soft-bodied robots

Robots with silicone bodies and flexible actuators (air muscles, electroactive polymers, and ferrofluids) look and feel different from robots with rigid skeletons, and can have different behaviours. Soft, flexible (and sometimes even squishy) robots are often designed to mimic the biomechanics of animals and other things found in nature, which is leading to new applications in medicine, care giving, search and rescue, food handling and manufacturing, and scientific exploration.[190][191]

Swarm robots

Inspired by colonies of insects such as ants and bees, researchers are modelling the behavior of swarms of thousands of tiny robots which together perform a useful task, such as finding something hidden, cleaning, or spying. Each robot is quite simple, but the emergent behavior of the swarm is more complex. The whole set of robots can be considered as one single distributed system, in the same way an ant colony can be considered a superorganism, exhibiting swarm intelligence. The largest swarms so far created include the iRobot swarm, the SRI/Mobile Robots CentiBots project and the Open-source Micro-robotic Project swarm, which are being used to research collective behaviors. Swarms are also more resistant to failure. Whereas one large robot may fail and ruin a mission, a swarm can continue even if several robots fail. This could make them attractive for space exploration missions, where failure is normally extremely costly.

Haptic interface robots

Further Information: Haptic Technology

Robotics also has application in the design of virtual reality interfaces. Specialized robots are in widespread use in the haptic research community. These robots, called "haptic interfaces", allow touch-enabled user interaction with real and virtual environments. Robotic forces allow simulating the mechanical properties of "virtual" objects, which users can experience through their sense of touch.

Contemporary art and sculpture

Robotic art

Robots are used by contemporary artists to create works that include mechanical automation. There are many branches of robotic art, one of which is robotic installation art, a type of installation art that is programmed to respond to viewer interactions, by means of computers, sensors and actuators. The future behavior of such installations can therefore be altered by input from either the artist or the participant, which differentiates these artworks from other types of kinetic art.

Le Grand Palais in Paris organized an exhibition "Artists & Robots", featuring artworks created by more than forty artists with the help of robots in 2018.[197]

Robots in popular culture

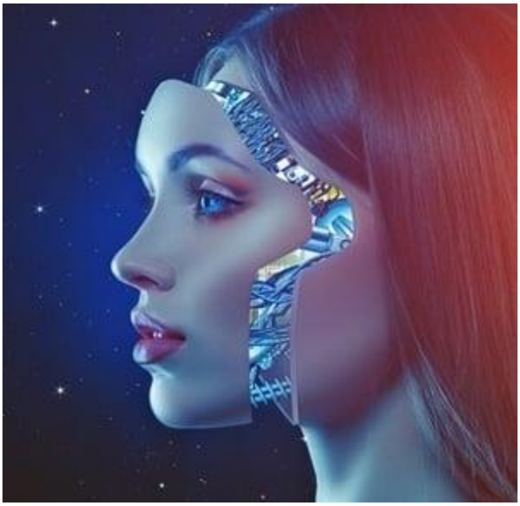
Robotic characters, androids (artificial men/women) or gynoids (artificial women), and cyborgs (also "bionic men/women", or humans with significant mechanical enhancements) have become a staple of science fiction.

The first reference in Western literature to mechanical servants appears in Homer's Iliad. In Book XVIII, Hephaestus, god of fire, creates new armor for the hero Achilles, assisted by robots. According to the Rieu translation, "Golden maidservants hastened to help their master. They looked like real women and could not only speak and use their limbs but were endowed with intelligence and trained in handwork by the immortal gods." The words "robot" or "android" are not used to describe them, but they are nevertheless mechanical devices human in appearance. "The first use of the word Robot was in Karel Čapek's play R.U.R. (Rossum's Universal Robots) (written in 1920)". Writer Karel Čapek was born in Czechoslovakia (Czech Republic).

Possibly the most prolific author of the twentieth century was Isaac Asimov (1920–1992) who published over five-hundred books. Asimov is probably best remembered for his science-fiction stories and especially those about robots, where he placed robots and their interaction with society at the center of many of his works. Asimov carefully considered the problem of the ideal set of instructions robots might be given to lower the risk to humans, and arrived at his Three Laws of Robotics: a robot may not injure a human being or, through inaction, allow a human being to come to harm; a robot must obey orders given it by human beings, except where such orders would conflict with the First Law; and a robot must protect its own existence as long as such protection does not conflict with the First or Second Law. These were introduced in his 1942 short story "Runaround", although foreshadowed in a few earlier stories. Later, Asimov added the Zeroth Law: "A robot may not harm humanity, or, by inaction, allow humanity to come to harm"; the rest of the laws are modified sequentially to acknowledge this.

According to the Oxford English Dictionary, the first passage in Asimov's short story "Liar!" (1941) that mentions the First Law is the earliest recorded use of the word robotics. Asimov was not initially aware of this; he assumed the word already existed by analogy with mechanics, hydraulics, and other similar terms denoting branches of applied knowledge.

Sex Robots



The concept of humanoid sex robots has drawn public attention and elicited debate regarding their supposed benefits and potential effects on society. Opponents argue that the introduction of such devices would be socially harmful, and demeaning to women and children,[343]while proponents cite their potential therapeutical benefits, particularly in aiding people with dementia or depression.

Sex robots or sex bots are anthropomorphic robotic sex dolls that have a humanoid form, human-like movement or behavior, and some degree of artificial intelligence.[344] As of 2018, although elaborately instrumented sex dolls have been created by a number of inventors, no fully animated sex robots yet exist. Simple devices have been created which can speak, make facial expressions, or respond to touch.[345]

There is controversy as to whether developing them would be morally justifiable. In 2015, Robot ethicist Kathleen Richardson called for a ban on the creation of anthropomorphic sex robots with concerns about normalizing relationships with

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[343] http://en.wikipedia.org/wiki/ Sex Robot# cite note- 205

[344] Proud Robosexual' Plans To Marry Robot When It's Legal". *Www.inquisitr.com*. 25 December 2016. Retrieved 13 March 2019.

[345] *Maras, Marie-Helen; Shapiro, Lauren R. (2017). "Child sex dolls and robots: More than just an uncanny valley". Journal of Internet Law. 21 (6): 3–21. Proquest 1973344803.*

machines and reinforcing female dehumanization.[346] Questions about their ethics, effects, and possible legal regulations have been discussed since then.[347]

Sex robots are still in a relatively early stage of development. While sex dolls have been available on the market for more than 20 years and there are accordingly established doll owner communities available for research, experienced users of sex robots are hardly to be found so far.[348] Nevertheless, the topic of sex robots has been treated quite intensively in international research since 2007, triggered by David Levy's monograph Love and Sex With Robots. A systematic research review from the year 2020 was able to identify 98 international academic publications on sex robots.[349] These academic sex robot publications focus on the following six research questions:

1. What are the appropriate theoretical conceptualizations of sex robots?
2. What are the main ethical aspects of sex robots?
3. What empirical findings on the use and effects of sex robots are available?
4. How are sex robots represented in art and media?
5. How should child sex robots be regulated legally?
6. What are the appropriate designs and design processes for sex robots?

The majority of the available academic sex robot publications deals with ethical aspects, focusing on both currently available sex robots (that have only very limited artificial intelligence and interactivity) and future sex robots (that are envisioned as

[346] Staff writer (15 September 2015). "Intelligent machines: Call for a ban on robots designed as sex toys". *BBC News*. Retrieved 7 September 2016.
[347] Balistreri, Maurizio, 1970- (2018). *Sex robot: l'amore al tempo delle macchine*. Roma. ISBN 978-88-6044-552-0. OCLC 1081098188
[348] *Döring, Nicola; Pöschl, Sandra (2018). "Sex toys, sex dolls, sex robots: Our under-researched bed-fellows". Sexologies. 27 (3): e51–e55. Doi:10.1016/j.sexol.2018.05.009. S2CID 150027875.*

[349] 'Proud Robosexual' Plans To Marry Robot When It's Legal". *Www.inquisitr.com*. 25 December 2016. Retrieved 13 March 2019.

being sentient and having a free will). While at least some findings on experienced users are available on sex dolls, corresponding empirical data on sex robot users are missing. The academic sex robot discourse is similar to the public discourse so far characterized by relatively striking ideas about strong positive or strong negative effects of sex robots. Weak as well as ambivalent effects, which are theoretically and empirically most probable, are rarely discussed.

Likewise, sex robots are often regarded and criticized as predetermined products. Rarely is it considered in the state of research so far that the appearance as well as the functions and target groups of sex robots can be actively designed, for example by and for women, queer people, older people or people with disabilities. Those human-centered design processes can be the subject of academic sex robot research as well.

The sex robot research community meets at the "International Love and Sex With Robots Conference"[350] series initiated by David Levy held for the sixth time in 2021 as the "6th International Congress on Love & Sex with Robots".

In September 2015, Kathleen Richardson of De Montfort University and Erik Billing of the University of Skövde created the Campaign Against Sex Robots, calling for a ban on the creation of anthropomorphic sex robots.[351] Richardson is critical of David Levy and argues that the introduction of such devices would be socially harmful and demeaning to women and children.[352]

In September 2015, the Japanese company SoftBank, the makers of the "Pepper" robot, included a ban on robot sex. The robot's user agreement states: "The policy owner must not perform any sexual act or other indecent behaviour".[353]

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350 international Love and Sex with Robots Conference website"

351 Moyer, Justin Wm. (15 September 2015). "Having sex with robots is really, really bad, Campaign Against Sex Robots says". *Washington Post*. Retrieved 7 September 2016

352 Staff writer (15 September 2015). "Intelligent machines: Call for a ban on robots designed as sex toys". *BBC News*. Retrieved 7 September 2016.

353 mccurry, Justin (28 September 2015). "No sex, please, they're robots, says Japanese android firm". *The Guardian*. Retrieved 7 September 2016.

Noel Sharkey, Aimee van Wynsberghe, and Eleanor Hancock of the Foundation for Responsible Robotics released a consultation report presenting a summary of the issues and various opinions about what could be society's intimate association with robots.[354] The report includes an examination of how such robots could be employed as a rehabilitative tool for sex criminals such as serial rapists or pedophiles. Sharkey warns that this could be "problematic" in terms of sex dolls resembling children and adolescents.[355]

There is considerable speculation about such technology coming from experts in the fields of philosophy, sociology and the natural sciences. John P. Sullins of Sonoma State University believes that sex robots will facilitate "social isolation"[356]and Lydia Kaye of Central Saint Martin's argue that sexual relations with robots will "desensitize humans to intimacy and empathy".[357] Furthermore, according to Chauntelle Tibbals, "nothing can replace the joy, sorrow, passion, and pain of an actual, unpredictable human interaction."[358]She further argues that only when interacting with another human can we experience our humanity and our identity, as opposed to interacting with a robot.[359]

The sex robots that have been created, as of 2018, primarily resemble women with exaggeratedly hyperfeminine features. In Barcelona, a sex doll brothel allows men to act out their fantasies where they can choose from a selection of flexible silicone

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[354] Sharkey, Noel; van Wynsberghe, Aimee; Robbins, Scott; Hancock, Eleanor (2017). *Our sexual future with robots*. The Hague, Netherlands: Foundation for

[355] Wakefield, Jane (5 July 2017). "Call for a ban on child sex robots". *BBC News*. Retrieved 28 October 2017.

[356] *Sullins, John P. (January 2012). "Robots, Love, and Sex: The Ethics of Building a Love Machine". IEEE Transactions on Affective Computing. 3 (4): 398–409. Doi:10.1109/T-AFFC.2012.31. S2CID 253828*

[357] Kaye, Lydia (10 February 2016). "Challenging Sex Robots and the Brutal Dehumanization of Women". *Campaign Against Sex Robots*. Archived from the original on 4 December 2016.

[358] Tibbals, Chauntelle. "Sex Robots Misquoting & Reason #74,193 I Only Do Written Interviews | Dr. Chauntelle Tibbals". Retrieved 2020-09-15.

[359] Spitznagel, Eric. "The Sex Robots Are Coming." Men's Health, June 2016, p. 144.

dolls and request that they be dressed in whatever outfit the man prefers.[360]Kathleen Richardson argues that these sex robots facilitate a powerful attitude towards women's bodies as commodities, and promote a non-empathetic interaction.[361] Experts argue that improving the gender diversity of those involved in developing this sex technology could help reduce possible harm, such as the objectification of women.[[362]Many scholars, including Richardson, argue that this reinforces the idea that women are property rather than human beings with free will.[363] Scholars such as Robert Sparrow from Monash University argue that the creation of realistic female sex robots, with the ability to refuse consent, further facilitates a rape culture. He believes that sex with these robots represents the "rape of a woman" and may increase the rate of rape in society, while also facilitating a general "disrespect for women" in society.[364] Furthermore, a sex robot called "Frigid Farah", whose personality is described as "reserved and shy", has caught the attention of several scholars. The manufacturer claimed that if you touch her "in a private area, more than likely, she will not be too appreciative of your advance".[365] Many scholars view this as indulging rape fantasies and facilitating a rape culture.

Prons And Cons Of Sex Robots

The following arguments have been made in favour of using robots for sex:

[360] Tibbals, Chauntelle. "Sex Robots Misquoting & Reason #74,193 I Only Do Written Interviews | Dr. Chauntelle Tibbals". Retrieved 2020-09-15.

[361] Kale, Sirin (28 February 2017). "Spain Opens First Sex Doll Brothel for Men Who Like Shagging Silicone". *Vice*. Retrieved 1 August 2019.

[362]"Let's talk about sex robots". *Nature*. 547 (7662): 138. July 2017. Bibcode:2017Natur.547.138.. Doi:10.1038/547138a. PMID 28703204. S2CID 4465574.

[363] Richardson, Kathleen (June 2016). "Sex Robot Matters: Slavery, the Prostituted, and the Rights of Machines". *IEEE Technology and Society Magazine*. 35 (2): 46–53. Doi:10.1109/MTS.2016.2554421. Hdl:2086/12126. S2CID 32282830.

[364] Sparrow, Robert (September 2017). "Robots, Rape, and Representation". *International Journal of Social Robotics*. 9 (4): 465–477. Doi:10.1007/s12369-017-0413-z. S2CID 28713176.

[365] "New sex robots have 'frigid' setting which allows men to simulate rape". *The Independent*. 2017-07-21. Retrieved 2020-09-15.

- Sex robots could provide an alternative for people with socially unacceptable or harmful sexual preferences (i.e., paraphilias), such as pedophila or bestiality [366]
- Sex robots could take the place of prostitution [367]and mitigate human trafficking.
- According to the Foundation of Responsible Robotics, pleasure-bots could provide a sexual outlet and companionship for elderly individuals in long-term care homes [368], an argument reminiscent of using robo-pets in nursing homes
- You could fulfill a lifelong dream of having sex with a robot that kind of looks like a creepy version of a celebrity.
- Having routine robot sex could make instances of non-robot sex (in which you have sex with a real, live, sweaty human) seem more satisfying [369] a satisfaction akin to eating Vera Pizza Napoletana after months of eating frozen grocery store pizza.

So, if sex-bots have the potential to mitigate human suffering, fill a niche, and make sex between humans more satisfying, then what's the big deal? Before getting to the crux of this big deal (spoiler alert: the current state of sex-bot affaires perpetuates

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[366] Knapton, S (2017, July 5th). Sex robots on way for elderly and lonely...but pleasure-bots have a dark side, warn experts. *The Telegraph*. Retrieved from http://www.telegraph.co.uk/science/2017/07/04/sex-robots-way-elderly-lonelybut-pleasure-bots-have-dark-side/

[367] Levy, D. (2009). Love and sex with robots: The evolution of human-robot relationships. New York.

[368] Ibid

[369] Bodkin, H (2016, December 20th). Sex will be just for special occasions in the future as robots will satisfy everyday needs. *The Telegraph*. Retrieved from http://www.telegraph.co.uk/science/2016/12/19/rise-sex-robots-will-make-people-appreciate-real-thing/

harmful gendered ideals of sexuality), I'll outline some cons of using robots for sex, which include the following:

- Robots haven't bought into the tinder hookup culture, so it's pretty hard to meet robots for sex using dating apps.
- Sex-bots could increase social isolation.
- Some argue that sex robots used to treat paraphilias, such as a child sex-bot, could reinforce paraphilic orientations, such a pedophilia. This is similar to the argument made against child sex dolls, which are currently illegal in the UK and are being debated in Canadian courts.
- Sex-bots are being created by (mostly) men with gendered ideas. This leads to robots being created with biased gender norms, which perpetuate preexisting stereotypes [370]. For example, sex-bots currently on the market have settings to reflect submissive (and even frigid) notions of female sexual companions [371].

Basing on the standards of Uganda where technology is still low, sex robots are on low key. Basing on my analysis sex robots are majorly used by youths and these include plastic vigina /plastic phyallus etc which youth use in masturbation. It is majorly proved by crime intelligence that sex toys adoption in Uganda will reduce on sexual harassment acts such as rape, defilement, sexual connotation etc. Sex toys will also reduce on the rate of Prostitution hence reducing on the spread of sexually transmitted diseases like Stds, HIV/AIDS etc.

The religious belief per my interaction with various Reverends, adoption of sex toys will lead to family neglect.

[370] Jackson Gee, T (2017, July 5th). Why female sex robots are more dangerous than you think. *The Telegraph*. Retrieved from http://www.telegraph.co.uk/women/life/female-robots-why-this-scarlett-johansson-bot-is-more-dangerous/

[371] Ibid 68

CHAPTER TWELVE

Robot Judges & Judicial Actors Of Artificial Intelligence

The route of technology is drawn by the needs of humankind. This has been a given fact since we had learned how to control fire. On the other hand, law follows this path with a distance, cautiously. Every judicial system prefers to be dynamic. However, it is always difficult to move for big organisms, they all have slow reflexes. Beyond its size, there is also a significant fact about law that it is conservative.[372]

There might have been a leap-forward step in the UK. A robot-judge algorithm was created; the more interesting part of this Project was the moment when researchers showed the algorithm some cases in European Court of Human Rights' jurisdiction. 79% of the decisions made by the algorithm matched with the Court's decisions. (2017) Studies continue to work on the algorithm to make it more functional. However, Dr. Nikolaos Aletras from the project does not agree with the idea that robots may take over the judges' vacancies, but he claims that the time for the algorithm to reach the level of efficient evaluation of the given facts in a case is close.[373]

Just imagine a robot-judge in charge: First we should notice that this robot would reach not just the legal codes, bylaws and jurisprudences, beside them it is going to reach all of the online images, state records, health reports, social media accounts etc. Secondly, this robot will have a full independency from holidays, humanistic excuses, judicial disqualification etc. The robot may accelerate all of the

[372] Article of Robots by Caner Yeşil

[373] http://www.legalfutures.co.uk/latest-news/robot-judge-ai-predicts-outcome-european-court-cases (24.11.2016)

procedural stages so it can finish the whole case within a trial: Justice comes with a light speed!

The difference between artificial intelligence and standard computers is self-learning. Basically, robots can train themselves. With experience, these robot judges or lawyers would be more irreproachable such as "AlphaGo Zero" of Google. AlphaGo Zero is an artificial intelligence that specialized in Go. After a while, it learns to play simply by playing games against itself, starting from completely random play. In doing so, it quickly surpassed human level of play and defeated the human champion. Likewise, there is no need to years of legal experience, it may be possible in some online hours. Is it possible to found a check & balance system on artificial intelligence? Besides Asimov's three rules,[374]UN has actions to regulate robotic and more. There are international meetings in Washington and other cities. It is clear that the global steps need to be taken, but shouldn't legal experts be quicker and more effective?

From another perspective, robots should not be our opponents. In today's world, computer simulations are widely used for educating young engineers, scientists etc. In time, the robot may be used as a tool in moot court, the parties (plaintiff and defendant) and the universities may take advantage of having a robot[375] The Robot Judge research, very first example of its kind, may also enlighten the legal reasoning habits of the judges. For instance, it is seen that most of the judges in the Supreme Court apply legal positivism to the cases; some of them adopt more radical approaches. The big question here is the procedural rules- which are the products of the hundreds of the years can be transformed into a systematic consistency what the algorithm needs? Is there a formula of conscience? To be clear, a decision made by a robot on a human rights violation case makes an unpleasant irony visible and bringing it to in front of us.

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[374] A robot may not injure a human being or, through inaction, allow a human being to come to harm.

[375] http://www.hukukmedeniyeti.org/haber/9546/robot-hakimler-cagi/ (25.11.2016)

Besides the robot judge research, we need to mention the two artificial intelligence lawyers. First, ROSS, the world's first artificially intelligent attorney; powered by IBM, recently landed a position at New York law firm Baker & Hostetler (one of the largest law firms of the US and the World, employs 900+ lawyers) handling the firm's bankruptcy practice. [iii]You can contact with ROSS through the website: rossintelligence.com
The machine is designed to understand language, provide answers to questions, formulate hypotheses and monitor developments in the legal system.

Second, Do Not Pay[376]. Do Not Pay is developed by a British teenager and currently available in the UK and New York. It is accessible through the website: donotpay.com It gives a possibility to get parking fines back in less than 30 seconds. Do Not Pay works through a chat window, using a friendly, easy-to- understand language, thus people choose to consult it instead of consulting to a 100 years old-grey haired institution.

In the light of all these inventions, it seems that the road of technology is passing by law. Technological increasing of developments in the field of law should make the lawyers to stop for a second and think. It is true that there are various problems and obstacles in the law, especially in the trial periods. But when we return to the proposition that the route of technology is drawn by the needs of humankind, did we reach the point where there is a need for artificial intelligence in law?

Artificial Intelligence And Judicial Decision-Making

As technology continues to change the way in which we work and function, there are predictions that many aspects of human activity will be replaced or supported by newer technologies. Whilst many human activities have changed over time as a result of human advances, more recent shifts in the context of technological change are likely to have a broader impact on some human functions that have previously been largely undisturbed. In this regard, technology is already changing the practice

[376]http://www.dailymail.co.uk/sciencetech/article-3589795/Your-AI-lawyer-IBM-s-ROSS-world-s-artificially-intelligent-attorney.html (25.11.2016)

of law and may for example, reshape the process of judging by either replacing, supporting or supplementing the judicial role. Such changes may limit the extent to which humans are engaged in judging with an increasing emphasis on artificial intelligence to deal with smaller civil disputes and the more routine use of related technologies in more complex disputes.[377]

HOW MIGHT ARTIFICIAL INTELLIGENCE CHANGE JUDGING?

To be sure, AI legal analysis is in its infancy; prognoses for it must be highly uncertain. Maybe there will never be an AI program that can write a persuasive legal argument of any complexity.

If an entity performs medical diagnoses reliably enough, it's intelligent enough to be a good diagnostician, whether it is a human being or a computer. We might call it "intelligent," or we might not. But, one way or the other, we should use it. Likewise, if an entity writes judicial opinions well enough more, shortly, on what "well" means here it's intelligent enough to be a good AI judge. (Mere handing down of decisions, I expect, would not be enough. To be credible, AI judges, even more than other judges, would have to offer explanatory opinions and not just bottom-line results.) [378]

The same should be true for judging. If a system reliably yields opinions that we view as sound, we should accept it, without insisting on some predetermined structure for how the opinions are produced.[379] Such a change would likely require

[377] (2018) 41(4) *UNSWLJ* 1114: https://doi.org/10.53637/ZGUX2213

[378] CHIEF JUSTICE ROBOTS by EUGENE VOLOKH

[379]*See* Harry Surden, *Machine Learning and Law*, 89 WASH. L. REV. 87, 95 (2014) (describing such an "outcome-oriented view of intelligence"). This is as true for decisions about procedural rules as about substantive rules: Even if the legal question before the judge is whether certain procedures should be followed, we should evaluate the judge's opinions, and not whether the judge arrives at the opinions through traditional human reasoning or through a computer program.

eventual changes to the federal and state constitutions.[380] But, if I am right, and if the technology passes the tests I describe, then such changes could indeed be made.

3.Use Persuasion as the Criterion for Comparison for AI Judges as Well as for AI Brief-Writers. Of course, if there is a competition, we need to establish the criteria on which the competitors will be measured. Would we look at which judges' decisions are most rational? Wisest? Most compassionate?

I want to suggest a simple but encompassing criterion, at least for AI judges' judgment about law and about the application of law to fact:

Persuasion

This criterion is particularly apt when evaluating AI brief writer lawyers. After all, when we hire a lawyer to write a brief, we want the lawyer to persuade the lawyer's reasonableness, perceived wisdom, and appeals to compassion are effective only insofar as they persuade. But persuasion is also an apt criterion, I will argue, for those lawyers whom we call judges. [381]

If we can create an AI brief-writer that can persuade, we can create an AI judge that can (1) construct persuasive arguments that support the various possible results in the case, and then (2) choose from all those arguments the one that is most persuasive, and thus the result that can be most persuasively supported. And if the Henry Test evaluator panelists are persuaded by the argument for that result, that means they have concluded the result is correct. This connection between AI brief-writing and AI judging is likely the most controversial claim in the paper.

Promote AIs from First-Draft-Writers to Decisionmakers. My argument starts with projects that; are less controversial than AI judges. I begin by talking about what should be a broadly accepted and early form of AI automation of the legal process: the use of AI interpreters to translate for non-English-speaking

[380] . *See infra* note 72 and accompanying text.

[381] CHIEF JUSTICE ROBOTS by EUGENE VOLOKH

witnesses and parties.[382] I then turn to AI brief-writing lawyers' software that is much harder to create, of course, but one that should likewise be broadly accepted, if it works.[383]

From there, I argue that AI judicial staff attorneys that draft proposed opinions for judges to review as well as AI magistrate judges that write reports and recommendations rather than making final decisions would be as legitimate and useful as other AI lawyers (again, assuming they work).[384] I also discuss AIs that could help in judicial factfinding, rather than just law application.[18]

And these AI judicial staff attorneys and magistrates offer the foundation for the next step, which I call the AI Promotion: If we find that, for instance, AI staff attorneys consistently write draft opinions that persuade judges to adopt them, then it would make sense to let the AI make the decision itself indeed, that can avoid some of the problems stemming from the human prejudices of human judges.[385] I also discuss the possible AI prejudices of AI judges, and how they can be combated.[386]

Just as we may promote associates to partners, or some magistrate judges to district judges, when we conclude that their judgment is trustworthy enough, so we may promote AIs from assistants to decision makers. I also elaborate on the AI Promotion as to jurors,[387] and finally move on to the title of this Article: AI judges as law developers.[388]

The rationale of this book is that the problem of creating an AI judge that we can use for legal decisions[389] is not materially more complicated than the problem of

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[382] *See infra-4*

[383]*See infra-4*

[384]*See infra-4*

[385] *See infra-6*

[386] *See infra-Part* 6

[387] *See infra-Part* 6

[388] *See infra-Part* 6

[389]Fact-finding is a somewhat different matter. *See infra-6*

creating an AI brief writer that we can use to make legal arguments.[390] The AI brief-writer may practically be extremely hard to create. But if it is created, there should be little conceptual reason to balk at applying the same technology to AI judges within the guidelines set forth below. Instead, our focus should be on practical concerns, especially about possible hacking of the AI judge programs, and possible exploitation of unexpected glitches in those programs;

[390]The slight extra complexity is discussed in infra-6: an AI judge also needs to have a module that compares two possible opinions and determines which of them is more likely to be persuasive.

CHAPTER THIRTEEN

Ai Lawyers as Brief-Writers

Now let's imagine someone designs something that's much further away than good interpretation software: a program that writes briefs. It takes all the record documents, figures out the legal issues and arguments that would be considered relevant by a judge in the particular jurisdiction, and produces a brief, whether trial level or appellate.[391] It is possible that AI will never get good enough at this. Processing all the documents contracts, statutes, precedents, witness testimony, emailsin the way needed to construct a persuasive legal argument might be too hard a task.[33] That is especially so since persuasive legal argument must be not only about applying clear rules was a document signed? did it need to be? but also about vaguer standards, such as "reasonableness" or whether the "probative value [of evidence] is substantially outweighed by a danger of . . . unfair prejudice."[392] And, perhaps hardest of all, such an argument has to deal with questions of credibility and factual inference: Which witness is telling the truth? Is someone's story internally consistent? Are certain allegations so improbable that we should require an especially great deal of evidence for them? But suppose that years from now, some company says that it has succeeded in solving these problems. After all, if AIs ever pass the Turing Test, that means they will be able to converse like ordinary humans do, at least in writing. Imagine, then, AIs that can converse like lawyers do, and

[391]By analogy to Chief Justice Robots, Neal Katy AI? "[P]perhaps artificially intelligent appellate advocates will play the role of the steam hammer in a folk tale about how Neal Katyal or Paul Clement was a brief-writing man who died slumped over the podium having defeated his computerized opponent." Travis Ramey, *Appellate A.I.*, APP. ISSUES, Nov. 2017, at 14, 19. 33. I am not suggesting that current "machine learning" tools for instance, ones that help with document review, *see, e.g.*, Julie Sobowale, *How Artificial Intelligence Is Transforming the Legal Profession*, ABA J., Apr. 2016, at 1, 1 are anywhere near what is required for this.

[392]FED. R. EVID. 403.

when asked to explain why their client should prevail on some issue can offer an answer indeed, an extended, brief-long answer on the subject.

Now, say you work for a business that is tired of paying lawyers top dollar for this work, so you're intrigued. But you obviously want quality legal work, and you wonder whether you're going to get it from the AI. Again, you would need to conduct a Henry Test, with the criterion being persuasion. Hire ten lawyers to write ten briefs each. Have the software write briefs on the same issues. Hire a panel of ten retired judges whom you trust to tell you which persuades them most, without their knowing who wrote what. If the AI is at least as good as the average human brief-writer, why would you go with the more expensive and no-more-effective human, when you can use the cheaper and possibly better (or at least equal) computer program?

The test will be expensive, but it can be run once on behalf of many potential clients. The software developer will likely pay to have the test run by a credible, impartial organization perhaps a panel of retired judges who are paid a flat fee up front. And if the software is at least as good as the average of the human lawyers, clients can save a vast amount of money going forward.[393]

To be sure, some could ask what is "really" going on in the process. Is the software "understanding" the precedents, the record documents, the policy arguments? Is it truly engaging in "analogical reasoning"?[394] Is it exercising "legal judgment"? Is it "intelligent"?

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[393]Indeed, some clients might be satisfied with software that is not even as good as the average of the human lawyers if it is sufficiently cheaper. But for the sake of simplicity, I focus only on the criterion being persuasiveness rather than (more precisely) persuasiveness relative to cost.

[394]Cass Sunstein, for instance, argues that analogical reasoning may be especially hard to program, because it requires arguments about value judgments. Cass Sunstein, *Of Artificial Intelligence and Legal Reasoning*, 8 U. CHI. L. SCH. ROUNDTABLE 29, 33–34 (2001). That might indeed hinder the development of good AI brief-writers because they would have to make arguments for making such judgments, and these arguments would require the software to go beyond the four corners of the precedent and the current case's fact pattern.

Yet intelligent is as intelligent does. There is nothing mystical about the result you, as a prospective client, seek you want the AI brief-writer to persuade your target audience to make the decision you want. That could be a monumentally difficult design problem. But if the software can accomplish that, that's all you need.

It might be better if we try to avoid, when possible, the language that we too closely associate with human minds. Instead of the software "understanding" some documents, we might be better off talking about the software determining how the legal rules can be persuasively argued to apply to the contents of the document. Instead of "intelligent," we can just say "effective."[395]

Of course, what persuades turns on the identity of the person you are trying to persuade. The software would have to be programmed accordingly, just as we teach young lawyers to act accordingly. The program would obviously have to recognize that different jurisdictions have different substantive rules. It might also recognize that different localities, and even different people, have different rhetorical preferences.

Yet the question should solely be whether we can develop software that is capable of this.[396] If at some point, we can do this (a big "if," I realize), then we would be foolish to forgo the cost savings and eventually the greater persuasion that the software can offer. Indeed, for many people, even a not very good AI lawyer may be better than no lawyer at all, especially if that is all they can afford.[397] Advancing

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[395] As Edsger Dijkstra famously put it as it happens, referring to Turing's work "t]the question of whether Machines Can Think . . . Is about as relevant as the question of whether Submarines Can Swim." THE YALE BOOK OF QUOTATIONS 205 (Fred R. Shapiro ed., 2006); Edsger W. Dijkstra, Speech to Association for Computing Machinery 1984South Central Regional Conference: The Threats to Computing Science (Nov. 16–18, 1984), https://www.cs.utexas.edu/users/EWD/transcriptions/EWD08xx/EWD898.html [https://perma.cc/CDS6-MRDA]. Submarines can propel themselves through the water, whether or not one calls it "swimming." If an AI can produce persuasive arguments, that is what matters, not whether this is done through a process we normally call "thinking," "reasoning," or "intelligence."

[396] Or, to be pedantic, asking the questions that match Jeopardy answers.

[397] *See* D'Amato, *supra* note 3, at 1286.

technology has helped put many formerly expensive goods clothing, food, entertainment, and more within reach of the poor.[398] Realistically, the only way we are likely to sharply increase access to expensive services, such as lawyering, is through technology.

If clients aren't comfortable with just relying on the AI software, they can use what we might call the AI Associate model: they can have the AI software write a first draft of the brief and then have an experienced human lawyer the equivalent of the modern partner or inhouse counsel review and edit it, for a fraction of the cost of writing it from scratch. This is similar to how many translators are already using machine translation,[399] though this process wouldn't work as well for real-time interpretation.

But even this review process might at some point become obsolete. Here, we can keep running the Henry Test: we can compare the unedited AI brief-writer with the combination of the AI brief-writer and a human editor to see whether there is a material difference in persuasion, measured, again, by a panel of judges who don't know which submission is which. If at some point, there is no measurable difference, then even the cost of human editing though much less than the cost of human beginning-to-end writing—might no longer be justifiable.[400]

Naturally, there will be political resistance to this by human lawyers, who may rightly worry that the AIs will take away human jobs. And human lawyers have considerable power, through their control of state bars, to suppress competition.[43]

But big businesses that are tired of paying vast sums for attorney fees have considerable power, too. I doubt that even lawyers will long be able to resist calls to allow such businesses to use the latest labour-saving technology. And once the

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[398] *See, e.g.*, *Make It Cheaper, and Cheaper*, ECONOMIST (Dec. 11, 2003), https://www.economist.com/special-report/2003/12/11/make-it-cheaper-and-cheaper [https://perma.cc/88AA-9333] (discussing how technology has made food cheaper).

[399] *See e.g.*, Rebecca Fiederer & Sharon O'Brien, *Quality and Machine Translation: A Realistic Objective,* J. SPECIALISED TRANSLATION, no. 11, Jan. 2009, at 52, 52.

[400] . Indeed, if the AI associates entirely replace human associates, then some decades later all the human lawyers will have retired or died, and there may be no one to provide legal editing

Microsoft's and GMs of the world can use AI brief-writers, less-powerful small businesses and consumers will likely be able to use the same technology. Indeed, I expect the prospect of AI brief-writers to be the main impetus for investing in developing AI legal-writing, technology, precisely because there is such a potential for savings for businesses here and thus such a potential for profit for AI developers.

FACT-FINDING ASSISTANTS[401]

We have been talking so far about staff attorneys that draft opinions applying law to facts. But judges also often have to find facts in bench trials, in injunction hearings, in preliminary decisions about the admissibility of evidence, and so on.[402]

Fact-finding is a different matter than law application, and it requires a different set of skills. It may require an ability to accurately evaluate a witness's demeanor as a guide to whether the witness is lying, evasive, or uncertain. It also requires an ability to consider consistencies and inconsistencies in each witness's story, as well as which witnesses and documents are consistent or inconsistent with each other. It requires an ability to evaluate human biases, human perception, and human memory. It is thus possible that good AI fact-finding software may be much harder to write than the AI Brief-Writer or AI Staff Attorney. [403]

On the other hand, AIs may have some advantages over humans here, partly because humans aren't very good at these things. First, there is some reason to think that a person's demeanor does offer some clues about whether the person is telling the truth, but that these clues are too subtle for most humans to pick up. Computers' greater processing speed and attention to detail may enable them to more effectively detect lies.[404]

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401 . I am particularly indebted in this Section to Jane Bambauer.

402 . *See, e.g.*, FED. R. EVID. 104(a) ("[A] court must decide any preliminary question about whether . . . Evidence is admissible.").

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404 . *See, e.g.*, Rachel Adelson, *Detecting Deception*, MONITOR ON PSYCHOL., July/Aug. 2004, at 70, 70 (discussing attempts to automate a system for evaluating facial expressions that are seen as

Second, whether various stories are mutually consistent is itself often hard to figure out, since it may require processing many days' worth of testimony, often boring testimony. Third, human decisionmakers are vulnerable to a wide range of biases that might make them trust some people too little and others too much.

To be sure, it's easy to imagine AIs that do worse than humans on some or all of these criteria. But suppose someone develops an AI that is not perfect, but that claims to do as well as humans do, or even better. Suppose also that the AI can produce not just its own evaluation of the facts, but some persuasive articulation of why that evaluation is correct.[66] That explanatory function is not strictly necessary to proving that the AI is a good factfinder, but it may be necessary to make the AI credible in the eyes of the public.

Here, too, we can test the AI with a Henry Test, but with a different testing criterion. We assemble, as usual, a group of contestants: one AI and several experienced human judges. We give them test cases that contain audio and video recordings of live testimony, coupled with documents and summaries of forensic information. The test cases are selected to cover a wide range of possible scenarios, with some witnesses lying, some telling the truth, and some mistaken.[405] The test cases should include difficult scenarios, in which the truth isn't obvious, as well as easier scenarios. But for all the test cases, we need to have considerable confidence that the truth is known to those who are running the test perhaps because there is some irrefutable piece of evidence that wasn't uncovered until later, or because we may exclude some evidence from the materials presented to the contestants.[406]

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cues to dishonesty); Jacek Krywko, *The Premature Quest for AI-Powered Facial Recognition to Simplify Screening*, ARS TECHNICA (June 2, 2017, 7:30 AM), https://arstechnica.com/information-technology/2017/06/security-obsessed-wait-but-can-ai-learn-to-spot-the-face-of-a-liar

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[406] To be sure, such test cases are not entirely representative of all factual disputes, since in many factual disputes there is no sure answer that one can use to test the AI judge's abilities. Still, if the AI judge does as well as or better than human contestants on those test cases, why should we have any less confidence in its performance on more ambiguous cases than we would have for the humans?

If the AI does at least as well as the human contestants at finding the truth, then we will know that it is a pretty good evaluator of factual accounts. It would at least be useful as an advisor to a judge, especially if as suggested above it can lay out a set of reasons for the factual results it reaches. And, as discussed below, we might consider actually allowing it to be a judge or juror, and not just an advisor.

JUDGES AND ARBITRATORS AS LAW-APPLIERS OR FACTFINDERS

The AI Promotion

HOW EVER MUCH we are only at Lawyer Robots and Staff Attorney Robots. And those two tools, if they can indeed be developed, would make the legal system much cheaper and quicker. A judge helped by AI staff attorneys can process cases much more quickly than a judge who lacks such help. Perhaps we should be satisfied with that.

Human judges, though, being human, have human prejudices. These may be prejudices based on race, sex, or class. They may be unconscious prejudices in favor of the good-looking, the tall, the charismatic. They may be prejudices in favor of lawyers the judge is friends with, or lawyers who contributed to the judge's election campaign. They may stem from a desire to curry favor with voters, with a President who might appoint the judge to a higher position, or with a Justice Department that recommends judges to the President for promotion. [407]

They may be prejudices in favor of litigants who have sympathetic, though legally irrelevant, life stories. Or they may be ideological prejudices in favor of certain claims or certain classes of litigants. The legal rules themselves will sometimes prefer such claims or litigants, but some judges might have their own preferences that aren't authorized by the law, or even by the legal system's unwritten conventions.

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Leaving decisions, or at least certain kinds of decisions,[408] entirely to AI judges may help avoid these prejudices.

Of course, it would be foolish to replace prejudice with incompetence. If, for instance, AI staff attorneys prove to be poor at important aspects of opinion writing such as making sure that any new rules the opinion proposes are seen by human evaluators as properly fitting the existing rules then that would be reason to insist on human review of such proposed opinions, or perhaps of all proposed opinions.

But say we have experimented with AI staff attorneys and found them highly reliable; that is, suppose human judges have found that the AI staff attorneys produce results that almost never have to be revised or second-guessed. And say we conduct the by-now familiar Henry Test and conclude that AI judges' opinions

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[408] . *See, e.g.*, Daniel Ben-Ari , Yael Frish, Adam Lazovski, Uriel Eldan & Dov Greenbaum, *"Danger, Will Robinson"? Artificial Intelligence in the Practice of Law: An Analysis and Proof of Concept Experiment*, 23 RICH. J.L. & TECH. 2, 35–36 (2017) (suggesting that "[m]ost commercial disputes and criminal sentencing will be run by algorithms and [AI]," avoiding judgments by "human beings [who are] prone to effects of emotion, fatigue, and general current mood" (citation omitted)). Indeed, some decisions, such as the application of sentencing guidelines, are already made using algorithms that could be applied in computer-assisted ways, even without AI. But those decisions still require analyzing documents or statements that provide the inputs to the algorithms such as the defendant's role in a criminal enterprise, the nature of the defendant's criminal history, and the like. They also generally provide for some discretion within the algorithms, such as choosing a sentence within a range. Our examples contemplate that this entire process would be computerized, which would require some AI. D'Amato suggests that even if there is resistance to the use of AI judges for what are seen as important substantive determinations, such decision making might first be tried as to procedural matters, where citizens might feel (rightly or wrongly) that there are fewer important normative principles at stake. D'Amato, *see also* Richard Re & Alicia Solow-Niederman, Developing Artificially Intelligent Justice 29 (Jan. 11, 2019) (unpublished manuscript) (on file with *Duke Law Journal*) (suggesting more broadly that "human/machine division of labor would apportion discrete types of judicial decision making to human as opposed to mechanized actors"). Whether AI procedural decisions are less controversial than substantive ones are a political question, on which I can't make any confident predictions. In any event, it seems likely that there will be some sorts of decisions for which AI judging will be more politically palatable, at least at first. And AI judging can be tested there, before there are attempts to spread it more broadly.

persuade a panel of evaluators perhaps, themselves retired human judges at least as often as do the opinions of human judges. [409]

Why not, then, promote the AI from staff attorney to judge? After all, that is often what we do when we find people's judgment reliable enough that they no longer need to be supervised by decisionmakers, but can become decisionmakers themselves. Associates are promoted to partners; interns and residents are promoted to attending physicians; magistrate judges are sometimes promoted to district judges.[410]

One way of thinking about such promotions is that the system switches from retail evaluation to wholesale. We start by asking people to make tentative decisions that are subject to review by other people whose judgment we trust. As law firm partners, for instance, we have associates write draft briefs that we then review. We evaluate the associate's work in each case, and we revise it or not as necessary.

But at some point, we make a global evaluation decision; we ask whether the associate's work product is good enough not perfect, but up to the standards of the partnership. If so, we promote the associate to partner, letting that one promotion-stage evaluation take the place of continued evaluation of the person's work product.[411]

To be sure, adopting AI judges would and should require special constitutional authorization, whether in state constitutions Article III of the Constitution is best understood as contemplating human judges, and likewise for similar state

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[410] . Perhaps it would be better if selection of human judges (or partners) involved such testing as well, rather than relying on credentials, reputation, or informal evaluation of past performance. Social convention, though, generally precludes this, except for a few kinds of jobs, and perhaps it would be too dispiriting for many people (at least in our society) to continue being subjected to formal tests well into their careers. Fortunately, we need not worry that AI judges might have such psychological reactions.

[411]of course, this is an oversimplification. Depending on the particular task, there may be senior associates who are not much supervised, or junior partners whose work is reviewed by more senior partners.

constitutional provisions.[412] But if AI judges are one day seen as providing better justice or equivalent justice at much lower cost and with much greater speed, we should be open to making such constitutional changes.

Humans, of course, develop their judgments over years of experience; AIs might not operate this way.[413] But the basic criterion for promotion should still be whether we trust the candidate's judgment. The Henry Test provides a good way to test that judgment. Suppose a panel of evaluators concludes that an AI judge program writes opinions that persuade them in the cases that are supplied to it as part of the test. If so, why not give the program decision making authority, rather than leaving its judgments subject to constant editing by a human judge?

For many legal questions, there will be many different arguments that are persuasive in the sense that we would give them high marks for legal craft. Most of us have the experience of having praised an argument as persuasive even if we ourselves have not been persuaded by it. But the question for our purposes is whether the opinion does indeed persuade the evaluators, not just that the evaluators are willing to compliment it as persuasive or as within the range of acceptable legal outcomes. If they are indeed persuaded, then by hypothesis they believe that the judge (whom they later see identified as an AI judge) has offered the correct legal analysis which, as I argue, is the criterion we should use for evaluating judges. How can we sensibly say, "You keep persuading me that your judgments are consistently correct, but you're still bad at judging"?[414]

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[412]The requirements that judge take oaths of office, *see* U.S. CONST. Art. VI, § 3, and receive salaries, help support that. And more broadly, I think the constitutional understanding of "judge" contemplates human officeholders with human virtues (and potential vices), so that a shift to technological judging would call for constitutional authorization. And this makes sense. Before we make such a dramatic change in our legal system, it ought to have super majoritarian support, likely developed as a result of extended experience with AI brief-writers, AI staff attorneys, and AI arbitrators.

[413] Machine learning may be seen as a form of experience, but a somewhat different kind.

[414]For more on whether we should resist accepting AI judges because of a worry that their opinions might persuade us in the short term, but prove unsound in the long term, see the human evaluators will surely have their own limitations hidden or subconscious biases, susceptibility to various fallacies, and the like. But that's the nature of human decision making, whether we're evaluating

AI judges would likely be expected to offer more written opinions supporting their judgments than we get from human judges, who often just issue one-line decisions. For human judges, we generally have to trust their exercises of discretion, whether based on our knowledge of the judge's character, our hope that judges are honourably following their oath of impartiality, or ultimately sheer necessity: courts' busy workloads don't let judges write detailed opinions supporting every decision on every motion. But AI judges have no personal bona fides that might make us trust them. Their written justifications are all that can make us accept their decisions.

Yet, if the AI technology can produce such written justifications, this also means that AI judges might well be more reliable and eventually more credible than human judges. Precisely because of these explanations, we could be more confident that their judgments are defensible than we would be with a black-box "here's what I think" that a human judge would offer.

Arbitration as a Test Bench. There should also be ample opportunity for the public to test AI judging before fully adopting it. Long before the public becomes willing to require litigants especially criminal defendants to accept AI judges, contracting parties would have an opportunity to consent to AI arbitration. Many businesses, naturally more concerned about time and money than about abstract legitimacy or human empathy, might prefer quicker and cheaper AI arbitration over human-run arbitration.

Indeed, even consumers and consumer-rights advocates might be open to such arbitration: while many arbitrators are suspected of bias in favor of some group (usually the repeat players), AI arbitrators could be verified to be at least largely bias free. A consumer-rights group, for instance, could agree with a business group to some set of test cases that would be submitted to the AI arbitrator, and some correct set of results (or ranges of results) that the AI arbitrator is expected to reach. If the AI arbitrator reaches those results, or some other results that, on balance, both sides

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prospective AI judges or prospective human judges. We have to choose judges somehow; in the absence of any truly objective metric, the best we can do is select evaluators whom we trust, and see who is best at persuading them.

view as acceptable, it can get both groups' seal of approval which should make the arbitrator's work more palatable to consumers, businesses, and judges who review the legitimacy of the arbitration agreements.

Of course, it's possible that the two sides so differ in their view of what the arbitrator should do that they can't agree on the proper results. Yet, as in the other scenarios, the question isn't whether the AI arbitrator is perfect. Rather, the question should be whether the AI is at least as good as a human judge or a human jury.

Say that the parties conclude that the answer is yes, and that an AI arbitrator will, on balance, reach results that are at least of roughly similar quality to the alternative whether a human judge, a human jury, or a human arbitrator. They should then prefer the AI arbitrator to the human alternative, because the AI arbitrator provides the same bang for a lower buck.

Parties should similarly be open to AI arbitration of collateral disputes, such as disputes about discovery or other pretrial matters, even when the final dispute is being adjudicated by a human. Indeed, AI arbitration might become especially popular as to some such disputes precisely because the disputes are generally so narrow, and thus (1) more likely to be adaptable to the early generations of AI adjudication programs, and (2) less likely to involve the sort of judgments about ultimate results that people might especially expect to be reached by humans. [415]

Choosing AI Judges Based On Ideology Or Judicial Philosophy

Whether an opinion persuades evaluators may vary based on their views about legal method: textualism versus purposivism in construing statutes, efficiency versus deontology in developing the common law, predictability versus flexibility of legal rules in either situation. And whether the opinion persuades may, naturally, vary based on the evaluators' views about which results are good or which moral

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principles ought to influence close calls about how to clarify or change the law.[416] This is part of why different people have different views about the qualities of various human judges (though there is also a good deal of overlap in people's evaluations). And that is especially so for people who are deciding which judges to appoint or confirm Presidents, Senators, Governors, and the like.

Yet lack of consensus about what judicial approaches are best simply means that there will likely be rival AI judges designed to take different approaches,[417] and that the process of selecting AI judges might remain a political process. We might thus decide not to have some ostensibly professionalized mechanism, through which a panel of experts selects the best AI program to serve as a Supreme Court Justice; instead, we might have an evaluator panel that consists of elected political leaders.[418] Different AI models might win different Henry Tests, depending on who the nominators and the evaluators might be. [419]

And the test cases for the Henry Test might deliberately include scenarios that the evaluators see as especially ideologically salient, as well as scenarios that represent more humdrum cases. The usually stated objection to asking nominees about

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[416]*See generally* ANTONIN SCALIA, A MATTER OF INTERPRETATION: FEDERAL COURTS AND THE LAW (1997) (collecting views on the subject by Justice Scalia, Gordon Wood, Laurence Tribe, Mary Ann Glendon, and Ronald Dworkin).

[417] Richard Posner suggested that "originalists and other legalists" should be "AI enthusiasts," chiefly as an argument against people who hold those positions. RICHARD POSNER, HOW JUDGES THINK 5 n.10 (2008). But pragmatists can be AI enthusiasts, too—just enthusiasts for AI programs that reach sound pragmatist results, which is to say, results defended by arguments that pragmatists see as sound. Posner also seems to take the view that AI judges would be best at "apply[ing] clear rules of law created by legislators, administrative agencies, the framers of constitutions, and other extrajudicial sources (including commercial custom) to facts that judges and juries determined without bias or preconceptions." *Id.* At 5. While those may be easier AI judges to design, I have in mind more sophisticated designs that take into account many other factors, including pragmatic considerations (or at least designs that do so no worse than judges who currently take such considerations into account).

[418]This assumes that the political offices have not been delegated to Ais but that is a story for another article.

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particular future cases[420]that a judge would feel obligated to stick to that decision when the case arises, and thus won't be open to new arguments that the lawyers could raise would not apply to computer programs, which presumably wouldn't worry about losing face by violating some implicit precommitment.

Even if an AI passes the Henry Test, there might still be a process through which political actors (the President, Senators, and the like) verify that they are comfortable with the AI judge's judgment[421]for instance, those actors could pose follow-up test cases to the AI judge, and see whether they are persuaded by the opinions the AI judge writes. On the other hand, if the political process decides that such questions about future decisions are improper, the programs can be programmed to refuse to answer such questions a better assurance than we have as to human judges, who might answer the questions behind closed doors. or the AIs could be programmed to instead only answer questions about how they would have decided past cases, one proposal that has been offered for confirmation of human judges.[422]

Indeed, this might work even for elected state supreme court justices: Advocacy groups could "interview" the AIs, and report on whether the AIs' analyses of various cases were to the advocacy groups' liking; voters could then consider these groups' endorsements in making their choice. Not a perfect tool for informed voter

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[420]*See, e.g.*, DENIS STEVEN RUTKUS, CONG. RESEARCH SERV., QUESTIONING SUPREME

COURT NOMINEES ABOUT THEIR VIEWS ON LEGAL OR CONSTITUTIONAL ISSUES: A

RECURRING ISSUE 1 (2010) (reviewing prior testimony by Supreme Court nominees and nominees' evasion of questions about particular future cases).

[421]political actors should do this whether the President and Senators, as today, or some other set of elected officials, or some specially selected or elected body. The important point is that if we want to have a political screening process, we can have one for AI judges that is at least as effective as our current process is for human judges.

[422].Vikram David Amar, *It's the Specifics, Stupid. . . . A Commentary on the Kind of Substantive Questions the Senate Can and Should Pose to Supreme Court Nominees*, FINDLAW (Aug. 4, 2005), http://supreme.findlaw.com/legal-commentary/its-the-specifics-stupid.html [https://perma.cc/8SZV-DHX6].

choice, to be sure, but likely no worse than the current situation when it comes to state appellate court elections.

Alternatively, voters could vote for human experts who then sit as the panel of evaluators that runs the Henry Test on prospective AI judges this is reminiscent of the occasional elections in which voters vote on delegates to a constitutional convention.[423] The experts can run based on their judicial philosophies, and the experts' past careers may be evidence of that: presumably the experts would be prominent retired human judges, respected former human lawyers, legislators who have substantial legal training or expertise, or legal academics. Perhaps, one day, AI brief-writers and AI judges will have so outcompeted humans that there will be no more retired human lawyers and judges who could evaluate the AIs' opinions.[424] But there will likely still be people who come to know the legal system, whether as scholars or activists, well enough to serve as evaluators.

One way or another, our hypothetical Chief Justice Robots will have been selected because the constitutionally prescribed decisionmakers whether they be the President and Senators, Governors, state legislators, voters, or specially elected experts have reason to think that they like Robots' likely future opinions. The decisionmakers find that the opinions match, as best as they can determine, their deeply held policy preferences, and they find that the opinions persuade them in those areas where they lack such preferences.

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[423] . This can happen when Congress calls for an amendment to the U.S. Constitution to be put to a vote by state-ratifying conventions, which was done for the Twenty-First Amendment. *See, e.g.*, IND. CODE § 3-10-5-1 (2018); WYO. STAT. ANN. § 22-20-202 (2017). And it happens more often when a state is revising its own constitution. *See, e.g.*, ARK. CODE ANN. § 7-9-302 (2018); NEB. STAT. § 49-212 (2018).

[424]*See supra* note 42. Just as individuals' reliance on algorithmic assistants can erode their personal decision-making skills, *see, e.g.*, Michal S. Gal, *Algorithmic Challenges to Autonomous Choice*, MICH. TELECOMM. & TECH. L. REV. (forthcoming 2019) (manuscript at 21), https://papers.ssrn.com/sol3/papers.cfm?Abstract_id=2971456&download=yes, it's possible that the legal system's reliance AI judging may over time leave us with many fewer humans knowledgeable about law.

That is how decisionmakers evaluate prospective human Chief Justices, to the extent they can gauge the human candidate's positions. Why should they reject an AI Chief Justice who is likely to satisfy their preferences for ideology and professional competence even better than a human Chief Justice?[425]

Humanity

many people are still likely to balk, how can we expect computers to decide questions about liberty, equality, democracy, and dignity? Human judges appreciate these things because they can feel pained by the lack of such things, and pleased by their presence an emotional response, though capable of rational analysis, stemming from lived experience. A computer judge can't feel or live these things, at least unless it develops emergent properties far beyond what its authors expect.[160] How can we expect an AI judge to make decisions without these inputs?

But here again what matters is the result, not the process. If a poetry-translation program reliably produces translations that are emotionally rewarding for us as readers, it should not matter to us that Robot Frost can't itself have emotions. If, in a blind test, we view an AI sentencing judge as producing wiser and more compassionate results by our lights than a human sentencing judge, it should not matter to us as evaluators that the judge can't have "wisdom" or "compassion."

Robots can't.[426] Perhaps this absence of emotional experience could keep the AI law-developing judge from ever passing even the blind graded Henry Test. But if

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[425]Thus, the answer to the question, "Should we say that, if we could be sure somehow that the decisions of the black box always would track those of the human judge, that we would have no preference between the two?" Robert D. Brussack, Review Essay, *The Second Labor of Hercules: A Review of Ronald Dworkin's* Law's Empire, 23 GA. L. REV. 1129, 1170 (1989), would be "yes." Or, at least, if the decisions of the AI black box would be routinely at least as persuasive as those of a human judge, it is hard to see why we should prefer the inscrutable silicon-based AI judge black box to the equally inscrutable carbon-based human judge black box.

[426]Indeed, emotions famously often lead us down the wrong path. Empathy might sometimes do the same. *See generally* PAUL BLOOM, AGAINST EMPATHY: THE CASE FOR RATIONAL COMPASSION (2016).

the AI judge can reliably produce opinions that persuade us given our emotions, why should it matter that it can't feel those emotions itself?

conclusively therefore technology may make it possible so transfigure society that it will make the AI judge unnecessary or irrelevant. If, for instance, the path to the AI judge will first take us to Skynet. Skynet will have much need for them. Or perhaps the technical that exercises constitutional judgment, rather than a traditional Supreme Court that decides "constitutional law." Again, this would require a constitutional change, but I don't see that as a barrier, developments that would allow AI judges will produce such vast social changes that they are beyond the speculation horizon, so that it is fruitless to guess about how we will feel about AI judges in such a radically altered world. And in any event, the heroes of the AI judge story will be the programmers, not the theorists analyzing whether Chief Justice Robots would be a good idea.[427]

My main argument has been that while we are planning for artificial intelligent judge, we need to scrutinize the following:

- We should focus on the quality of the proposed AI judge's product, not on the process that yields that product.
- The quality should largely be measured using the metric of persuasiveness.
- The normative question whether we ought to use AI judges should be seen as turning chiefly on the empirical question whether they reliably produce opinions that persuade the representatives that we have selected to evaluate those opinions. If one day the programmers are ready with the software, we should be ready with a conceptual framework for evaluating that software.

[427] As Sibelius supposedly said, no one has ever built a statue honoring a critic. BENGT DE TÖRNE, SIBELIUS: A CLOSE-UP 27 (1938).

CONCLUSION

COPYRIGHT

There are two ways in which copyright law can deal with works where human interaction is minimal or non-existent. It can either deny copyright protection for works that have been generated by a computer hence contributing to the public domain or it can attribute authorship of such works to the creator of the program.

The Copyright and Neighboring Rights Act of Uganda 2006 provides that computer programs are eligible for copyright protection[428]. This caters for AI software programs as long as they satisfy the requirements for copyright protection i.e., originality. However, although the act protects AI computer programs, it does not cater for works autonomously generated by AI programs. Uganda's current copyright law on authorship only allows human authorship and updating the law to grant person-hood to Al for purposes of authorship does not look a probable option because it does not solve the question of who grants licenses nor who would enforce the IP rights in case of infringement. Basically, IP rights should be allocated in such a way as to provide for an incentive to invest in the development of AI. Granting copyright to the person who made the operation of artificial intelligence possible seems to be the most sensible approach, with the UK's model looking the most efficient. Such an approach will ensure that companies keep investing in the technology, safe in the knowledge that they will get a return on their investment.

However, on the other hand, developing countries like Uganda that have weak domestic scientific and technological base, relying on acquisition of foreign-owned technology and know-how to support industrial development, the public domain can be utilized for technological learning and incremental

[428] Section 5 of the Copyright and Neighbouring Rights Act 2006.

innovation. Whether this is a desirable option, largely depends on the economic assessment. Copyright law should seek to strike an appropriate balance between incentives for innovators and avenues for competitors to access technology-relevant information. Whereas it can be argued that leaving AI-generated works unprotected will diminish the incentives to invest and develop AI technologies, the public domain can also be seen as a balancing counterweight to copyright's over expansion as well as an important inspiration for human creativity. First, works created by AI when left in the public domain will serve as a valuable pool of inspiration, which creative individuals may use without fearing copyright infringements. Additionally, given AI's potential for unlimited creation of works, if these works were protected, it is easy to imagine a rapid and unbalanced growth in Al-generated copyright protected works which may ultimately hinder free imitation and creation.

PATENTS

Since AI cannot claim inventorship rights in autonomously generated creations, it would be futile to amend the law to provide for AI as the inventor in Al-generated creations. This is because the inventive capacity by AI may not be disclosed during application for patents and humans may list themselves as inventors as has happened before with Thaler's creative machine. Alternatively, it has been argued that AI is incapable of being incentivized to innovate and only does that which it is taught or has learnt to do. Therefore, the most practical approach may be to vest inventorship in Al-generated creations in the inventor who has developed the program creating the AI. This would encourage further investment and innovation in AI programs that autonomously generate works.

Countries like Uganda at an early stage of technological development depend to a great extent on informal means of technology transfer by imitation, reverse engineering and, at a more advanced stage, adaption to local conditions.[429]

[429] United Nations Conference on Trade and Development, 'Development Dimensions of Intellectual Property in Uganda: Transfer of Technology, Access to Medicines and Textbooks', UNCTAD/*PCB/2009113.l2.*

Accordingly, Uganda's 2007 Communication to the WTO Council for TRIPS of Priority Needs for Technical and Financial Cooperation emphasizes the importance of the public domain as a source of knowledge building and technology absorption[430]. Therefore, this study advocates for the need to adopt the level of intellectual property protection that are reflective of Uganda's actual level of development and the needs for technological learning, and incremental innovation. Hence, this book recommends the need to recognize the importance of public domain in regulating Artificial Intelligence in Uganda. Therefore, it would be worthwhile to expand Uganda's public domain by making reforms to patent law so that local innovators who rely on information available in the public domain can access technologically- relevant information. These local innovators should be granted some form of protection to prevent competitors from wholesale copying of their inventions by using second tier categories of IPRs such as utility models or trade secrets since they generate less impact on the public domain.[431]

Sections 10(2) and (3) lay down a strict novelty standard, providing that any written or oral prior art publicly available in any country of the world shall destroy the novelty of an invention claimed in Uganda. By restricting the possibilities to claim existing inventions as new, this section contributes to the safeguarding of a public domain needed for domestic researcher's freedom to operate.[432] In order to preserve in the public domain technological developments that are predictable from existing prior art, section 11 that provides for the inventive step standard should be amended to specify that the assessment of non-obviousness of the invention need not be based on a local person skilled in the art, but rather on skills existing anywhere in the world. This would contribute to the development of AI technology by preserving public domain.[433]

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[430] *Ibid*

[431] United Nations Conference on Trade and Development, 'Development Dimensions of Intellectual Property in Uganda: Transfer of Technology, Access to Medicines and Textbooks', UNCTAD/*PCB/2009113.13.*

[432] *Ibid 13.*

[433] Ibid 14

This book postulates that a sui generis regime governing legal personality of AI, the same as that governing Company law, be adopted in Intellectual property law to carter for key AI techniques like deep learning, where AI is able to generated work without human supervision. This is based on the fact that most AI may in future acquire the ability to act autonomous without a human programmer. The law should be proactive to carter for such future eventualities.

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ABOUT THE BOOK

Due to an impressive evolution of the artificial intelligence technologies within the last few decades it has become an integral part of everyday life called for improving and facilitating it. This book covers the background, purpose, methods, delimitation of artificial intelligence. The presentation of artificial intelligence by examining its historical evolution in order to track an appearance of the idea of ascription of legal personhood to artificial intelligence and its justifiability through the lens of technological advancement.

Next differing academic and legislative approaches to the definition of artificial intelligence, defining features of artificial intelligence and list of such features constitutive for the conferral of legal personhood on artificial intelligence.

The book covers the possibility of endowing artificial intelligence with legal personhood. It is dedicated to the observation of such phenomenon as personhood by touching upon the classical, psychological and ethical concepts of person and upon the modern approaches to the notion of person in philosophy, including the utilitarian and libertarian theories

Also the interrelation of personhood and legal personhood is inspected by analyzing approaches. This discussion is inconceivable without defining the legal personhood. The book also covers the types of legal personality, such as natural and artificial persons

Potential recognition of personhood and legal personhood for artificial intelligence is discussed therein accepting an idea of the ascription of legal personhood to artificial intelligence, a question of the type of such legal personality is studied by way of comparison of the artificial intelligence's determining features with the corresponding characteristics of humans.

The implications of the conferral of legal personhood on artificial intelligence in the commercial context that is unveiled by dint of contract and tort law, intellectual property rights. The problem of contracting artificial intelligence is examined through the proposed solutions, such as treating artificial intelligence as a mere tool, applying agency law to it and recognizing it as a legal person. In the sphere of tort law, a liability problem related to the unpredictability of artificial intelligence's behavior aggravated by the involvement of various parties is discussed from and as of intellectual property rights, authorship of works and inventions autonomously created by artificial intelligence is observed from the theoretical and practical standpoints, paying attention to the advantages of conferral of legal personhood on artificial intelligence.