Social Impact Of AI Technologies

Mr. Suresh Kashinath Ghatge[1*], Prof.(Dr.)Anuradha Parasar[2]

Abstract

AI or Artificial Intelligence is among the most transformative and effective technologies humans have ever needed. From a price quote from Amazon or movie recommendation from Netflix to OCR and nonlinear controls, AI took the world by storm and is transforming everything in a different way. To be specific, AI is a concept which combines large datasets to solve queries as part of computer science. It is considered by some experts as the technology to enable machines and computers to perform on their own. It is also considered as a machine which replaces manual efforts to provide faster and more efficient results. Some consider it as a system that can interpret data, learn from it, and use what it has learned accurately to accomplish specific tasks and goals.

Issues faced by mankind in this day have been very complex, which require coordinated, large-scale activities across the countries and across different NGOs and government organizations. Artificial Intelligence can solve some of the most challenging social issues in the world. Hence, this study is aimed to discuss some of the social benefits of AI technologies, risks and ethical and governance concerns of AI in this day and age.

Keywords: Artificial intelligence, social benefits of AI, OCR, computer science, machine learning, governance, ethical concerns

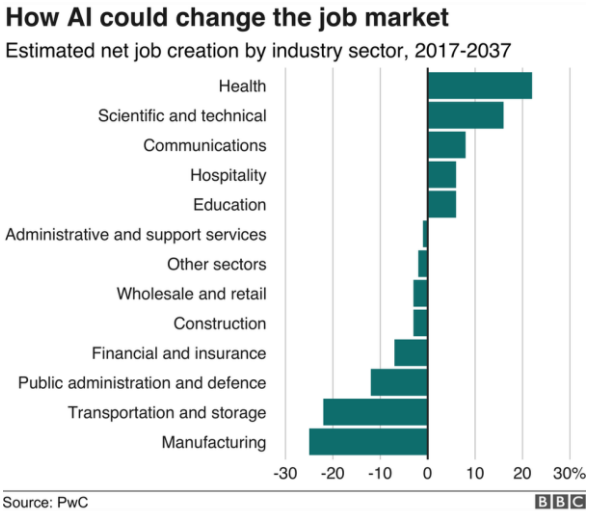
[1*]Ph.D. Research Scholar, Liberal Arts(Sociology), MIT WPU Pune(Maharashtra),India,
Email: suresh.k.ghatge@gmail.com
[2]Professor of Liberal Education Galgotia University, Greater Noida, Uttar Pradesh, India,
Email: anuradhaparasar99@gmail.com

***Corresponding Author:** Mr. Suresh Kashinath Ghatge
*Ph.D. Research Scholar, Liberal Arts(Sociology), MIT WPU Pune(Maharashtra),India,
Email: suresh.k.ghatge@gmail.com

1. Introduction

AI will certainly evolve the current workforce. The alarming headlines held machines responsible for the loss of jobs, but the actual challenge is to find passion with new roles which need completely different human abilities. As reported by accountancy giant PwC, AI would replace over 7 million existing jobs from 2017 to 2037 in the UK alone, but it could create around 7.2 million jobs (BBC, 2018) (Figure 1). Such changes and uncertainty can be challenging for someone to make a living.

Figure 1 – Estimated Jobs to be Replaced and Created by AI in various industries (2017-2037)



Source – BBC (2018)

AI would have transformative impact on modern society which will have far-reaching regulatory, economic, political, and legal implications which should be discussed and prepared for. Figuring out whom to hold responsible in case a self-driving vehicle hurts a passer-by or a global race of having automatic arms are just a few examples of challenges to face. Will humans lose control eventually or machines turn out to be super smart? It is a big question because the consequences are always uncertain with the introduction of latest technology. Those unexpected outcomes of AI would surely be challenging to mankind.

It is also important to ensure that AI will not become so excellent in doing its job that it crosses all the legal or ethical limits. Although the original goal and intention of making AI is benefit of mankind. If it decides to achieve the desired goal in any way possible, it would adversely affect the society. The AI models should be designed to align with the all-embracing goals of humans. Big data powers the AI models. The more the data AI collects about every moment of the day, the more the privacy will be compromised. If government and businesses choose to make decisions on the basis of intelligence (like China's social credit), it could be decentralised into social tyranny (Locker, 2018).

1.1 Background

AI can drastically improve the efficiencies of businesses and augment the manual processes. When artificial intelligence replaces dangerous or mundane jobs, it can help human workforce to focus on more important tasks which require empathy and creativity. Job satisfaction and employee engagement can be improved if they are doing what is more interesting to them. With better diagnostic and monitoring potential, AI can drastically affect healthcare (Marr, 2017). By improving medical and healthcare operations, artificial intelligence can save money and operating costs. According to McKinsey, big data can save up to $100 billion every year for pharma and medicine sectors. Patient care would be truly impacted. Patient care can be life-changing with personalized treatment and drug protocols along with better access to data (Cattell et al., 2013).

The society can gain endless productivity by just introducing AI and autonomous transportation to handle the problems of traffic jams and on-the-job productivity. Humans can spend more time in several other tasks as they would be free from stressful ups and downs. AI will also enhance criminal investigation process and help solve complex cases for law enforcement agencies. Facial recognition can be a boon for various industries. AI can also help in justice system without affecting someone's privacy. AI is going to have a significant impact on everyone's life, unless they choose to never interact with modern world by living

remotely. As technology rolls out with new applications, there will be several learning curves and experiences. AI is expected to have more positive impact on society and do better (Marr, 2019).

2. Literature Reviews

Gómez-González et al. (2020) provided an insight to near-future and existing applications of AI in healthcare and medicine and classified the same as per their social and ethical aspects, potential risks and benefits, and issues which might be controversial and not discussed well in academia. They analyzed the state of the art of technology and research like personal monitoring devices, software, editing tools and genetic tests, personalized models, AR devices, online platforms, and companion and surgical robots. They described "extended personalized medicine" and reviewed existing AI applications in healthcare and medicine and explored the public perception of AI and medical systems.

The use of digitalization and AI is making a significant technical and social transformation. AI scholarship and governments have endorsed important AI principles but they are directionless at the level of implementation. Ashok et al. (2022) discussed the ethical use of digital technologies and AI beyond high-level principles. They identified 14 implications of digital ethics for using AI in 7 digital technology archetypes. The implications of accountability, fairness, intelligibility, and autonomy and privacy are the most discussed topics.

The digital transformation means transformation of mankind, not just at industrial level, but also at intelligence level. Social transformations are made at a rapid pace but their challenges cannot be dealt by one company alone. Various stakeholders can play their part with paradigms of open innovation around the citizen-oriented perspective. It is still important to define the impacts of AI to the societies and there is a lack of action when it comes to reveal the social impact of AI (Vilariño, 2022).

As tech companies are facing public pressure to consider social implications of their products, governments and industries in the race of AI are calling for technical talent. Universities are aimed to add technical machine learning and AI courses into their curriculum to meet the increasing demand. Garrett et al. (2020) explored two ways for adding ethics in AI training – (1) integrating ethics in technical courses and (2) individual ethics courses. As computer scientists are trained on who will deploy and build AI tools, there is a question on how they are trained to consider the effects of their work.

Smart Factory is a complex system which consists of all the key aspects of Industry 4.0, such as, IoT, Big Data, and autonomous robots. Smart tools, robots, and workpieces collaborate and communicate well with one another constantly. Making production more efficient, competitive, sustainable, and flexible are required in smart factories. Along with introducing the concept of Smart Factories, Benotsmane et al. (2019) showed the application of simulation and AI approaches. They have summarized the social, economic, and operational impacts and needs of smart factories as well as characteristics of Smart Factory and traditional settings.

2.1 Research Gap

Technological advancements are going to have a great impact on the society. Though artificial intelligence can provide a lot of social benefits, there are also several risks associated with it. Hence, this article would discuss the benefits of AI in various discoveries that are helpful to society, possible risks like intentional misuse, insidious impact of social media, discrimination, and autonomous weapons, and practical solutions to make ethical use of this technology for the betterment of society.

2.2 Research Questions

- What are the benefits of artificial intelligence to society?
- What are some of the social implications of AI?

- How to resolve common challenges and make the best use of AI for the betterment of society?

2.3 Research Objectives

- To explore potential benefits of artificial intelligence to society
- To find out various risks of AI in different ways
- To suggest potential solutions to make the best use of this technology

3. Research Methodology

In order to assess the state of artificial intelligence in various aspects of society and to fulfil the above objectives, this study is based on secondary data gathered from various relevant studies and online sources.

4. Analysis of Study

4.1. Potential Benefits of Artificial Intelligence to Society

Latest technologies emerged with interactions of human intelligence and AI like deep learning are already having a great impact on society in areas like manufacturing, information services, healthcare, etc. and deeply affecting the "ways people live, work, and think. There are several benefits of AI to the society in the following ways –

4.1.1. Sustainability

Restoring and preserving global environment irrespective of pollution and climate change is the significant challenge for present society. Deep learning and AI can help deal with climate change in different ways (Rolnick et al., 2019). More reliable and accurate prediction of human activities is one common way by integrating big data from weather stations, satellites, simulation, etc. Use of energy by data centers worldwide has been increased over the past decade irrespective of ever-rising demands (Masanet et al., 2020).

4.1.2. Healthcare

Medical diagnosis has been very important with AI research lately. With big data and machine learning, data sets like brain imaging and genomics are used for prognosis and diagnosis of several illnesses (Uddin et al., 2019; Esteva et al., 2017). AI researchers have also applied machine learning for the diagnosis of disease from CT or X-ray images during COVID-19 (Jamshidi et al., 2020; Desai et al., 2020). Big data is also widely used to predict the spread of virus and number of positive cases and fatalities (Arik et al., 2020).

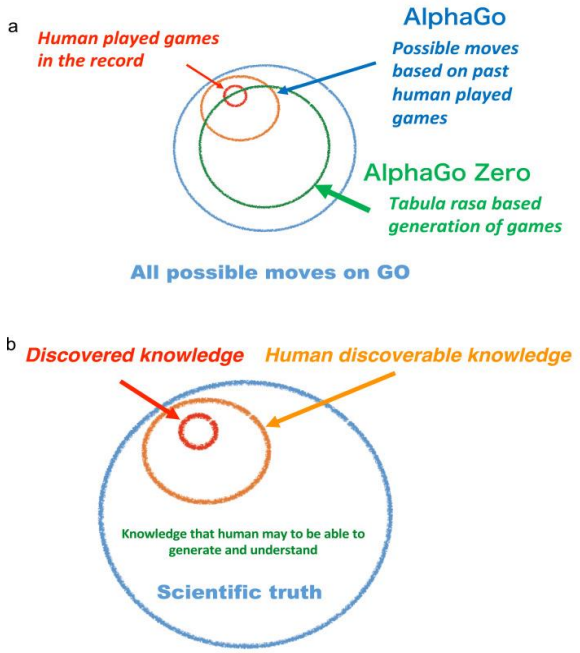
4.1.3. Scientific Discoveries

AI is capable to redefine scientific discoveries with massive verification and searches. But there are some implications to progress further. First example is Shinya Yamanaka's discovery of iPS cells. Yamanaka was awarded a "Nobel Prize in Physiology and Medicine" in the year 2012 (Takahashi & Yamanaka, 2006). They found 24 candidate genes to initialize the cell from FANTOM database. Then, they performed "single-gene knock-out" tests to detect the four factors important for inducing "pluripotent stem cells". Another example is "conducting polymer thin film" discovered by MacDiarmind & Heeger who bagged a "Nobel Prize in Chemistry" in the year 2000 (Shirakawa et al., 1977). Hence, efficient research labs are needed to make the most of AI assistants to help in scientific discoveries. For example, the "GARUDA platform" is used to connect simulators, databases, and other tools for "multi-omics data analysis" and heart arrhythmias prediction (Ghosh et al., 2011).

4.1.4. Scientific Experiments

Fixed, single pipeline is not sufficient for autonomous AI scientist (Kitano, 2016). One of the famous examples is AlphaGo, which was based on generation of hypothesis with a verification and policy network by a "Monte-Carlo tree search" (Silver et al., 2016). It was started with a large range of datasets and explored billions of self-plays simulated until it could defeat humans. Instead of using human data, AlphaGo Zero became more capable with further refinement than its predecessor or humans (Silver et al., 2017). Humans use strategies that can be understood they are comfortable with, but machines are used to explore the space in different ways that cannot be imagined by humans (Figure 2a).

Figure 2 – (a) All possible moves on AlphaGo and Zero (b) Scientific truth and knowledge discovered and discoverable by humans



Source – Silver et al. (2016; 2017)

In Figure 2(a) AlphaGo started with a big data of human playing and explored billions of self-play simulations to defeat humans (Silver et al., 2016). AlphaGo Zero became more capable to human players with further improvements (Silver et al., 2017). In Figure 2(b), humans can ask limited questions as per their research careers and cognitive ability. If every question can be answered quickly by hyper fast hypothesis testing, AI scientists may not find asking the right questions important. All in all, it is possible to find alternative ways of scientific discovery at a rapid pace with AI scientists. But there are also ethical concerns to be addressed when it comes to create autonomous intelligence which can evolve in itself.

4.2. Social Implications of AI

The joint progress in neuroscience and AI has made superhuman AI agents a reality, which were once science fiction. However, there are some ethical and governance concerns. When it comes to develop something with a goal, it is also important to consider the risk of failure or unexpected use to fulfill the purpose. Since mankind is deeply engaged in technology and science, they are also distressed with the misuse of science and technology (Wiener, 1960). Scientific and technological developments have opened new opportunities to human civilization and it had ultimately caused several accidents and incidents. Several incidents have been discussed where technologies were gone out of control or misused like "Climategate" and the "Chernobyl disaster" by Collins and Pinch (2012; 2014). They questioned the social structures and experts' responsibility. Hence, there is a need to consider the risks of AI and responsibilities of engineers and researchers in AI.

4.2.1. Planned Abuse

Along with accidental disasters due to latest technologies, it is also important to worry about intended abuses. Deep fake is the common example of how AI shouldn't be used as people can use it for malicious or mischievous intent. There are different misuses of AI which lead to cybercrime, a trillion-dollar global problem. It can get worse when we lose control on AI (Gillespie, 2015).

4.2.2. Battlefields

AI can also be used in making automatic lethal weapons which can be more serious and dangerous (Russell, 2015). Robots can be built to replace humans and robots in battlefield can be a serious dilemma. If machines are given the power of making decisions, there might be a risk of losing control in attacking humans. Robots are currently used for anomaly detection like drones but they are not as versatile and flexible as humans.

4.2.3. Cognitive Growth

With advancements of machine learning and gadgets, it is feasible to gather brain signals from electrodes implanted in the brain. Though the "brain machine interface (BMI)" can provide a lot of benefits to patients with "amyotrophic lateral sclerosis (ALS)" or "spinal cord injuries", it can also increase ethical and security concerns. Everything which is online is vulnerable to cyberattacks these days. How is it possible to prevent brain hijacking from attacks to connected devices?

4.2.4. People's Decisions

Even without brain electrodes, AI has already affected how people see their environment and make decisions. AI recommendation and classification programs trained by outputs given by humans can learn inequality and biases and reinforce the same. Researchers have made efforts to get rid of unethical biases from learned results or training datasets, but the issues are even deeper in interactions among users and AI. There are social media algorithms which choose what videos and news articles people should watch and read to occupy most of their time every day. These algorithms are made to increase click-through, engagement, and followers.

4.2.5. Social Gaps

Humans are already natural cyborgs (Clark, 2001). People depend on online spaces for processing information and memories. Communication records and scheduling are recorded in online spaces. Writings, research, and meetings can no longer be achieved without information devices and services. Robotics and AI stealing jobs and increasing unemployment is a common fear about AI. Some people argue that robotics and AI can help people in different jobs and creates more new jobs and businesses. What is reality is a blend of both scenarios. AI is causing disparities in societies having people who use AI, create AI, and those who do neither and act as sources of data for AI.

4.3. Potential Solutions to Make the Best Use of this Technology

AI research which enables superhuman or human-like intelligence also raises concerns over the interface between technology, science, and society. It is scientists' responsibility to imagine how they would apply their research to society. It is very important to discuss governance and ethics of the research.

4.3.1. Human-friendly AI

The founder of computer science and, perhaps, the founder of AI, Alan Turing published a most popular research paper "*Computing Machinery and Intelligence*", laid out some basic concepts of AI and defined the "Turing test" (Turing, 2009). According to his predictions, machine learning can be used to build AI systems. There is a need to find out why better AI often leads to worse consequences. There are also possible scenarios when hateful or greedy people can use AI to attack or exploit others. Even without intent of harm, AI can still lead to problems.

4.3.2. The "Provably beneficial AI"

A new model for AI is needed which is "Provably Beneficial" (Russell, 2019). If AI is designed with right principles, it can help and avoid illicit objectives. There are three right principles of its kind. First is that the only goal of a robot should be to meet human needs. Apart from what kind of pizza user loves, human preferences can be anything humans care for the future. Apart from individual preferences, it should care of preferences of the whole humanity, which may vary significantly in societies.

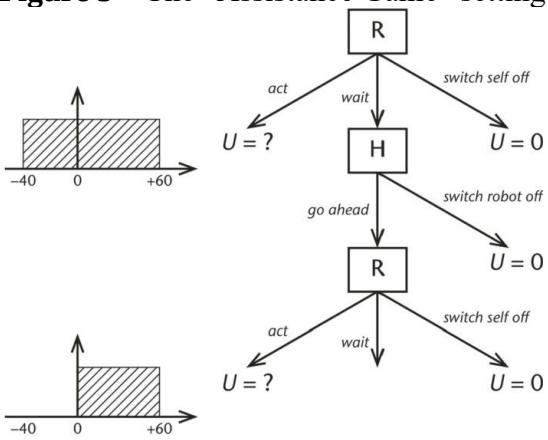
Another principle is that robot shouldn't know about those preferences. With this uncertainty, it is possible to design safe AI systems. Third one is that robot should learn about preferences from the given evidence. Instead of giving whole evidence of preferences, it should be imperfect as humans don't behave perfectly all the time. These principles can be turned into "assistance game" (Shah et al., 2019; 2020). When the robot is uncertain about the consistency of its plan with human preferences, it is encouraged to seek permission before initiating the plan (Figure 3). In Figure 3, the "robot (R)" is aimed to meet uncertain preferences of "human (H)" by learning through their interactions. Robot is encouraged to seek permission or be turned off instead of just acting when action's "utility (U)" may be adverse.

4.3.3. The "Turn-off scenario"

A robot which is assisting a human can be turned off in extreme cases. It is the core of control error. The better the AI, the better will be the results. Since AI can better learn human preferences, it can better help them in achieving goals. The robot can have an explicit goal (like fetching a coffee) if developers choose to go classical. For

example, a robot commands itself like, "I must bring the coffee. I can't do so if I am dead". Hence, I must disable my turn-off button". This is what should be avoided in new model.

Figure 3 – The "Assistance Game" setting

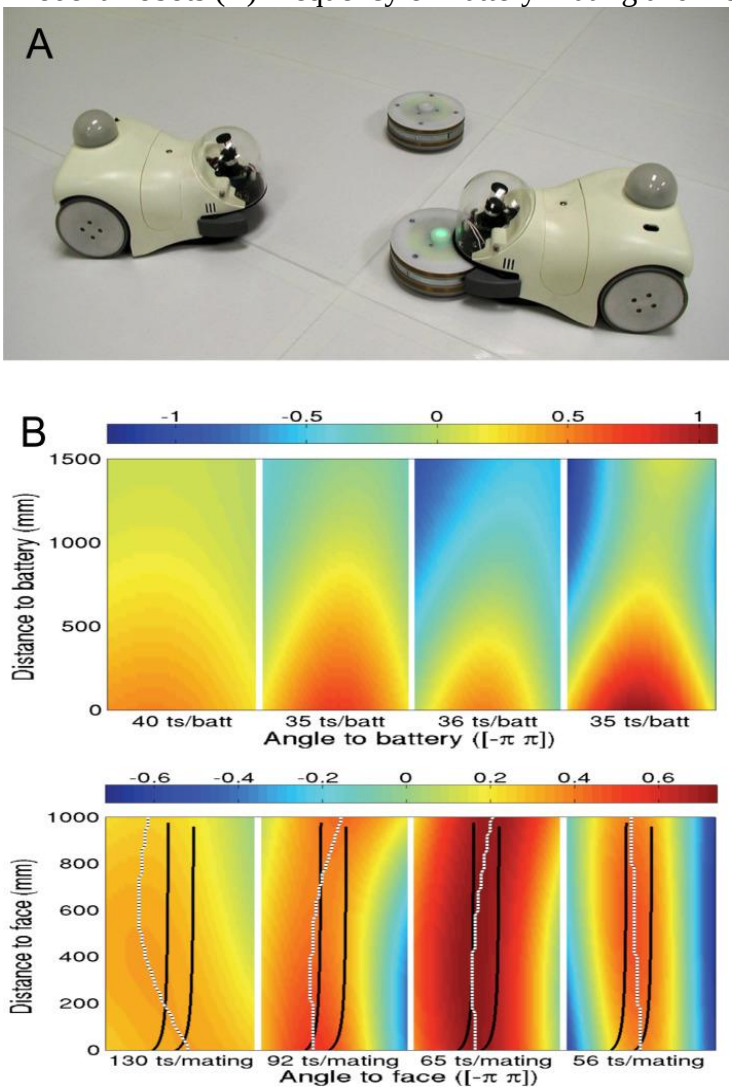


Source – Russell (2019)

4.3.4. Autonomy and Society

A lot of machine learning models are aimed to maximize or minimize the function. A "reinforcement learning agent" can learn to enhance the needed reward. But designing the right reward function is not trivial in any way. It is found that reward functions to encourage "software-reproduction" and survival can be attained by personified evolution in robot colony in a range of works which involved "Cyber Rodents (Figure 4) (Elfwing et al., 2011). Robots used various reproductive techniques in some colonies (Elfwing & Doya, 2014). It is also found that AI agents are capable to set goals on their own as reward functions to avoid being turned off or discharged, to gather data, and to reproduce.

Figure 4 (A) Cyber Rodent Robots (B) Frequency of Battery Mating and Acquisition by robots



Source – Doya & Uchibe, 2005; Elfwing et al., 2011)

In Figure 4(a), there are two basic functions of "Cyber Rodent robots" – battery recharge for survival and program parameters exchanged by infrared network for "software reproduction (Doya & Uchibe, 2005). When internal battery is depleted by a robot without proper recharging, the battery is discarded from the colony. When genes (programs) are exchanged by the robots by IR networking (mating), it adds small noise for mutation. In Figure 4(b), different reward functions for battery pack are promoted with evolution framework for constant battery mating and acquisition (Elfwing et al., 2011).

5. Results

In this day and age, those AI agents are needed which can set their goals and learn to achieve them. They may deliver latest technologies, make scientific inventions, form new bonds, and start new businesses, but there is a need to be careful on the risks they present at the same time. Even though those creative AI agents are almost perfect in their jobs, they may have consequences which are not easy to predict. Some of those agents may be uncontrollable or behave irregularly in some unexpected situations with some parameter setting. AI agents can be used by extremists to satisfy their hatred, greed, or ambition, which is the most immediate risk.

It is important for AI to learn from the minds which create society and from human society to address those risks. Although AI could be dangerous, humans are dangerous too. Mankind has already eradicated a lot of species on this planet, and may do the same to itself too because of its intelligence, i.e., by polluting the environment or waging nuclear war. However, human society also has mechanisms to avoid those disasters. Democracy is one of those mechanisms to avoid over-concentration of power in any group or person, which usually causes misuse of resources, war, or tyranny.

Humanity would be working with different AI agents with different experience. It would be obvious to prepare AI agents with wisdom of democracy in future. Merely one AI program shouldn't be given unlimited control on the world. There must be multiple AI programs with overlapping capacity to deliver services. Using heterogenous AI agents to form communities can be helpful to avoid abuse of power (Montes & Goertzel, 2019).

6. Conclusion

A lot of researchers specialized in neuroscience and AI are looking for the answers of basic questions related to humanity. For AI researchers, there is a lack of ethical prescription. But it is for sure that humans shouldn't proceed with their business as usual in AI world. It is important to adopt the recent technical foundation to lead to better designs of AI system. Overlooking governance and ethics in AI can risk the survival and reputation of the organization. There is a need to consider governance and ethical concerns of robotics and AI. Researchers in humanities and social sciences should have proper knowledge of brain science and AI for making vital discussions on their risks.

References

1. Arik, S., Li, C. L., Yoon, J., Sinha, R., Epshteyn, A., Le, L., ... & Pfister, T. (2020). Interpretable sequence learning for COVID-19 forecasting. *Advances in Neural Information Processing Systems*, *33*, 18807-18818.
2. Ashok, M., Madan, R., Joha, A., & Sivarajah, U. (2022). Ethical framework for Artificial Intelligence and Digital technologies. *International Journal of Information Management*, *62*, 102433.
3. BBC (2018). AI will create as many jobs as it displaces - report. Retrieved 5 April 2023, from https://www.bbc.com/news/business-44849492.
4. Benotsmane, R., Kovács, G., & Dudás, L. (2019). Economic, social impacts and operation of smart factories in Industry 4.0 focusing on simulation and artificial intelligence of collaborating robots. *Social Sciences*, *8*(5), 143.
5. Cattell, J., Chilukuri, S., & Levy, M. (2013). How big data can revolutionize pharmaceutical R&D. *McKinsey Center for Government*, *9*.

6. Clark, A. (2001, July). Natural-born cyborgs?. In *Cognitive Technology: Instruments of Mind: 4th International Conference, CT 2001 Coventry, UK, August 6–9, 2001 Proceedings* (pp. 17-24). Berlin, Heidelberg: Springer Berlin Heidelberg.
7. Collins, H. M., & Pinch, T. (2012). *The golem: What you should know about science*. Cambridge University Press (2nd ed.).
8. Collins, H., & Pinch, T. (2014). *The golem at large: What you should know about technology*. Cambridge University Press.
9. Desai, S. B., Pareek, A., & Lungren, M. P. (2020). Deep learning and its role in COVID-19 medical imaging. *Intelligence-Based Medicine*, *3*, 100013.
10. Doya, K., & Uchibe, E. (2005). The cyber rodent project: Exploration of adaptive mechanisms for self-preservation and self-reproduction. *Adaptive Behavior*, *13*(2), 149-160.
11. Elfwing, S., & Doya, K. (2014). Emergence of polymorphic mating strategies in robot colonies. *PloS one*, *9*(4), e93622.
12. Elfwing, S., Uchibe, E., Doya, K., & Christensen, H. I. (2011). Darwinian embodied evolution of the learning ability for survival. *Adaptive Behavior*, *19*(2), 101-120.
13. Esteva, A., Kuprel, B., Novoa, R. A., Ko, J., Swetter, S. M., Blau, H. M., & Thrun, S. (2017). Dermatologist-level classification of skin cancer with deep neural networks. *nature*, *542*(7639), 115-118.
14. Garrett, N., Beard, N., & Fiesler, C. (2020, February). More than" If Time Allows" the role of ethics in AI education. In *Proceedings of the AAAI/ACM Conference on AI, Ethics, and Society* (pp. 272-278).
15. Ghosh, S., Matsuoka, Y., Asai, Y., Hsin, K. Y., & Kitano, H. (2011). Software for systems biology: from tools to integrated platforms. *Nature Reviews Genetics*, *12*(12), 821-832.
16. Gillespie, A. A. (2015). *Cybercrime: Key issues and debates*. Routledge.
17. Gómez-González, E., Gomez, E., Márquez-Rivas, J., Guerrero-Claro, M., Fernández-Lizaranzu, I., Relimpio-López, M. I., ... & Capitán-Morales, L. (2020). Artificial intelligence in medicine and healthcare: a review and classification of current and near-future applications and their ethical and social Impact. *arXiv preprint arXiv:2001.09778*.
18. Jamshidi, M., Lalbakhsh, A., Talla, J., Peroutka, Z., Hadjilooei, F., Lalbakhsh, P., ... & Mohyuddin, W. (2020). Artificial intelligence and COVID-19: deep learning approaches for diagnosis and treatment. *Ieee Access*, *8*, 109581-109595.
19. Kitano, H. (2016). Artificial intelligence to win the nobel prize and beyond: Creating the engine for scientific discovery. *AI magazine*, *37*(1), 39-49.
20. Locker, M. (2018). China's terrifying "social credit" surveillance system is expanding. Fast Company. Retrieved from https://www.fastcompany.com/40563225/chinas-terrifying-social-credit-surveillance-system-is-expanding.
21. Marr, B. (2017). The Amazing Ways How Artificial Intelligence And Machine Learning Is Used In Healthcare. *Forbes*. Retrieved from https://www.forbes.com/sites/bernardmarr/2017/10/09/the-amazing-ways-how-artificial-intelligence-and-machine-learning-is-used-in-healthcare/?sh=4a9ec91f1c80.
22. Marr, B. (2019). What is the impact of artificial intelligence (AI) on society. *Intelligent Business Performance, dostupnona: https://bernardmarr. com/default. asp*.
23. Masanet, E., Shehabi, A., Lei, N., Smith, S., & Koomey, J. (2020). Recalibrating global data center energy-use estimates. *Science*, *367*(6481), 984-986.
24. Montes, G. A., & Goertzel, B. (2019). Distributed, decentralized, and democratized artificial intelligence. *Technological Forecasting and Social Change*, *141*, 354-358.

25. Rolnick, D., Donti, P. L., Kaack, L. H., Kochanski, K., Lacoste, A., Sankaran, K., ... & Bengio, Y. (2022). Tackling climate change with machine learning. *ACM Computing Surveys (CSUR)*, *55*(2), 1-96.
26. Russell, S. (2015). Take a stand on AI weapons. *Nature*, *521*(7553), 415-416.
27. Russell, S. (2019). *Human compatible: Artificial intelligence and the problem of control*. Penguin.
28. Shah, R., Freire, P., Alex, N., Freedman, R., Krasheninnikov, D., Chan, L., ... & Russell, S. (2020). Benefits of assistance over reward learning.
29. Shah, R., Krasheninnikov, D., Alexander, J., Abbeel, P., & Dragan, A. (2019). Preferences implicit in the state of the world. *arXiv preprint arXiv:1902.04198*.
30. Shirakawa, H., Louis, E. J., MacDiarmid, A. G., Chiang, C. K., & Heeger, A. J. (1977). Synthesis of electrically conducting organic polymers: halogen derivatives of polyacetylene,(CH) x. *Journal of the Chemical Society, Chemical Communications*, (16), 578-580.
31. Silver, D., Huang, A., Maddison, C. J., Guez, A., Sifre, L., Van Den Driessche, G., ... & Hassabis, D. (2016). Mastering the game of Go with deep neural networks and tree search. *nature*, *529*(7587), 484-489.
32. Silver, D., Schrittwieser, J., Simonyan, K., Antonoglou, I., Huang, A., Guez, A., ... & Hassabis, D. (2017). Mastering the game of go without human knowledge. *nature*, *550*(7676), 354-359.
33. Takahashi, K., & Yamanaka, S. (2006). Induction of pluripotent stem cells from mouse embryonic and adult fibroblast cultures by defined factors. *cell*, *126*(4), 663-676.
34. Turing, A. M. (2009). *Computing machinery and intelligence* (pp. 23-65). Springer Netherlands.
35. Uddin, M., Wang, Y., & Woodbury-Smith, M. (2019). Artificial intelligence for precision medicine in neurodevelopmental disorders. *NPJ digital medicine*, *2*(1), 112.
36. Vilariño, F. (2022). Unveiling the social impact of AI through living labs. In *Artificial Intelligence and Innovation Management* (pp. 233-257).
37. Wiener, N. (1960). Some Moral and Technical Consequences of Automation: As machines learn they may develop unforeseen strategies at rates that baffle their programmers. *Science*, *131*(3410), 1355-1358.