Ethics in Robotics: Being More Mindful as Engineers

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Kai Barzdukas

Spring 2023

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Advisor

Pedro A. P. Francisco, Department of Engineering and Society

Ethics in Robotics: Being More Mindful as Engineers

From robotic arms that manufacture goods with superhuman precision to autonomous drones capable of delivering goods over large distances, robots are at the forefront of accelerating the development of technology. For these reasons, among others, the vast applications and importance of robotics as a growing industry cannot be understated. However, this is not to say that robots come without consequences. While certain robots such as combat drones are considered unethical or ‘morally grey’, various aspects of the robotic design and production process of seemingly harmless robots have their set of not readily apparent repercussions. For example, electronic components used in robots such as embedded microcontrollers, FPGAs (Field Programmable Gate-Arrays), or ASICs (Application Specific Integrated Circuits) often use rare-earth metals and semiconductive elements (IEEE, 2023). A long-standing issue being that these metals are often unethically sourced from third world countries for a fraction of their worth – being exploitative in such cases (Cameron, 1979). This thesis looks to answer how regulatory and policy-making bodies have impacted the development and goals of robot design.

This research question is important to be mindful of, particularly for engineers working in robotics or adjacent fields, although some lessons may apply to any field. Professionals who understand these aspects of the robot creation process can help prevent design decisions and production mistakes that currently cause repercussions such as excessive carbon footprints, the predation of third-world countries, or artificial intelligence and machine learning-capable robots imbued with harmful characteristics. Realizing how the production process can be made to become more ecologically friendly is among one of the many ways that these unethical consequences can be mitigated by engineers.

It is also important to understand that even the most innocuous seeming of robots can cause side-effects or lead to the endangerment of people. The use of social robots to assist humans with various public services, for example, have the obvious future challenge of being exploitative or physically endangering to the elderly, disabled, or children if poorly designed. Along with this, current views regarding such robots introduce another set of indirect issues. An extensive survey held by almost 30 countries in the European Union reported a staggering 90% response in the distrust of robots tasked with helping the elderly or children (Bogue, 2014). Despite this, policymakers are focused on introducing robots to the same groups of people due to their natural applications in trivial but time-demanding labor (Lember, 2019). A fear with implementing laws such as these without the consent of the governed is the backlash which may cause civil unrest, distrust of the government, or the setback of relevant robotic technologies in areas that desperately require it (Willems, 2022)

The idea of technological determinism, where a society is shaped and developed by the technology it develops, can be seen in the inherent ability of engineers to instill their personal beliefs and values into their designs (Salsone, 2020). This unconscious bias that affects the development of technology explains much of why robots can be created to be unintentionally unethical. An example of how technological determinism has led to unintentional failures in technology can be seen with facial recognition software which could not detect the faces of minorities – particularly those with darker skin tones. This was due to the training of said facial recognition software conducted solely using Caucasian images (Najibi, 2020). With robotics overlapping a great deal with the machine learning tools used by facial recognition software, it is possible that a similar accident may occur under the wrong circumstances.

An important tool used to determine the ethic level of something is the philosophical idea of moral relativism. Moral relativism is the belief that moral truths are relative to specific cultures or individuals, and that there are no absolute moral standards that apply universally (Westacott, no date). Using actions that are publicly seen as unacceptable or unethical as existing benchmarks, other actions within a similar scope can be placed on a relative scale of 'more ethical' or 'less ethical' in a specific society. This relies on using an existing set of cultural values – in this case being an American view. A simple example is how most modern societies may find war waging civilizations of the past as barbaric; but given the environment and landscape of that era, was a cultural norm that was not considered unethical. Moral relativism is at the crux of how we can argue that an action is unethical and thus will be used liberally in conjunction with other literary tools to answer the research questions of unintended consequences of robotics.

Another large part of answering the research questions will come from the Actor-Network Theory (ANT) framework typically used in the field of Science, Technology, and Society (STS). With ANT, robots can be broken up into systems of individual components with specific functions and more importantly, ethical stigmatisms (Latour, 1992). This can pinpoint problematic design choices or components which may cause ethical issues. Furthermore, the overarching web of actors in the field of robotics which includes the engineers, literature, and major events can showcase connections between various nodes in the actor-network web. Importantly, these connections should showcase the cause-effect relationship of problematic design decisions and their impact.

The question of how policies and regulations concerning robotics have influenced robotic design and production can be answered by analyzing the cause-effect relationships of relevant judicial legislature. Policy and agency reports are crucial for ecological concerns in pollution stemming from the production of computer parts. Law involving robots created for the purpose of causing harm and robots unintentionally causing harm will likely highlight the visible ethical concerns with robotics. For these reasons, using legal rulings, policy documents, and agency reports in conjunction with the cause-effect nature of the ANT framework will be at the core of how this research question will be answered.

From a set of cause-effect relationships, the breakdown of certain robot designs and their components is the next step. Looking at how much pollution a component creates, the use of unethically sourced materials, areas with a particular susceptibility to bias, or parts that can be exploited by malicious actors are all particular interest regarding the effects of these relationships. These can be compiled to surmise what components or robots are unethical and more importantly, what might be done in order to prevent such consequences in future designs.

One of the most significant ethical concerns pertaining to the field of robotics is its impact on employment. As robots become more advanced and capable of performing complex tasks, there is a risk that they replace human workers. In fact, the use of robots in manufacturing has already started the trend for the replacement of human workers in factories or other positions involving trivial work. According to a study by MIT, one robot in manufacturing replaced around 3.3 workers hired for the same manufacturing positions (Dizikes, 2020). This replacement leads to job loss and economic instability for workers in these low-skill jobs. Another concern is that the use of robots in certain industries, such as healthcare, could lead to a reduction in the quality of care provided to patients. In a 2017 study held by the Pew Research Center, 59% of US adults felt that they would not be interested in a robot caregiver, with many citing that it would leave caretakers feeling ‘isolated’ (Smith, 2017).

To combat concerns regarding employment, governments and regulatory bodies around the world have recognized the need for laws and regulations to protect against the loss of jobs caused by advancements in robotics and automation. In South Korea, the Robot Ethics Charter originally created in 2007 includes a commitment to "consider the impact of robots on employment and take measures to minimize negative effects." (Young, 2019) In the United States, the Workforce Innovation and Opportunity Act includes provisions to support workers affected by job loss caused by automation and technological change. The act provides funding for job training and retraining programs, as well as support for displaced workers seeking new employment opportunities (WIOA, 2014). In 2017 and 2019, to directly combat the impact of technological change on employment, several reports were written by the International Labor Organization's Global Commission on the Future of Work under the United Nations (UN). The commission directly names policies and initiatives to support workers affected by job loss caused by automation and technological change (ILO, 2017). Following the Future of Work, multiple members of the UN cited the commission for policymaking efforts regarding automation in employment (ILO, 2022).

In the case of robotics and employment, rather than focusing on the designs or production of the robots, lawmakers have tweaked labor laws so that low-skill workers and others that would otherwise be left without jobs are able to find other work or have had their work integrated into the era of automation. The reasoning behind this is sound, as the use of robots to trivialize monotonous work if employment is not made impossible for the workers being replaced should lead to more fulfilling work and overall increased happiness. With blue collar workers reporting that they feel lower overall levels of happiness, retraining workers for 'happier' fields and leaving grueling labor to machines may be the most ethical solution regarding automation and employment (De Neve and Ward, 2017). Of course, with monetary incentives being at the top of motivations for labor, ensuring that the general quality of living and wages for displaced workers is of utmost importance. Overall, for ethical questions surrounding automation of labor, the responsibility lies on lawmakers more so than engineers.

Along with employment, another major ethical concern related to robotics is the potential for robots to be used for directly unethical purposes. For example, robots can be programmed to engage in criminal activities, such as theft or espionage. The use of drones to spy on people has been a famous distasteful use of robots (Gogarty, 2017). Related to this, in a vast majority of US states the use of drones to spy on unsuspecting people is not currently illegal under federal law (Martin, 2019). And while there exist “No-Fly Zones” in government-owned areas, there is little engineers can do to improve the social security of drones without compromising the functionality of these technologies. Unfortunately, this is another case of policymaking being the simpler solution rather than engineers finding methods of preventing such misuses.

The famous Mirai malware botnet created in 2016 which targeted insecure internet of things (IoT) devices and hijacked them for distributed denial-of-service (DDoS) attacks has showcased how any technology with computer elements can be used to commit a new category of cybercrimes (Fruhlinger, 2018). As a direct result of the Mirai botnet attacks, the state of California mandated that manufacturers of IoT devices equip the technology with reasonable safety features (Martinez, 2018). While IoT DDoS attacks are still a prevalent issue due to older technologies without fixes being implemented or developers being complacent with safety measures, engineers and IoT device manufacturers have acknowledged the dangers of botnet attacks and have taken steps to secure IoT devices from being misused in the future (Al-Hadhrami, 2021).

As the use of robots continues to increase across industries, it is important to consider their environmental impact. One key factor to consider is the carbon footprint of robots - the amount of greenhouse gases emitted during their production, operation, and disposal. The carbon footprint of robots can be divided into three main components: production, operation, and disposal. The production of robots requires significant amounts of energy, which is often generated through the burning of fossil fuels (Ritchie, 2022). The materials used in the production of robots also contribute to their carbon footprint. For example, the production of metals and plastics used in robots requires significant amounts of energy and emits greenhouse gases (STMicroelectronics, 2023). Acquiring these materials also often causes damage to the surrounding environments where they are extracted or created (Welle, 2021).

Like all electronic devices and similar technology, the operation of robots has its own carbon footprint. If the energy used to power robots comes from fossil fuels, it can significantly increase the robot's carbon footprint (Ritchie, 2022). Additionally, the transportation of robots, as well as the energy required to maintain and repair them further contributes to their carbon footprint (RSS, 2021). Finally, the disposal of robots also contributes to their carbon footprint. When robots reach the end of their useful life, they need to be disposed of, often resulting in non-negligible amounts of waste. While not as pertinent as the creation and use of robots, the disposal of robots can contribute to greenhouse gas emissions if they are not thrown away properly. For example, if they are sent to landfills and contribute to methane emissions (Groover, 1986).

A common "green" issue, the carbon footprint of robots has several implications for the environment. The greenhouse gases emitted during the various stages of robot use contribute to global warming and climate change. Like automobiles and electrical devices in our homes, as the use of robots continues to increase, their carbon footprint could cause significant concerns for the global climate. Although we have seen great strides in industry to lower the overall number of emissions since calls to action several decades ago, it is important to improve and maintain a high-level of environmental consciousness with robots as well (EPA, 2019)

To achieve this, reducing the carbon footprint of robots is crucial to mitigate their environmental impact. An obvious method to reduce the carbon footprint of robots is to use renewable energy sources to power and operate them (Hassan, 2020). Additionally, using energy-efficient components and systems can also reduce the energy required to power and operate robots (Maheswaran, 2016). Another way to reduce the carbon footprint of robots is to use sustainable materials in their production. For example, the use of recycled or biodegradable materials can significantly reduce the environmental impact of robots (Snow, 2021). Designing robots for longevity and ease of repair can reduce the need for replacement and disposal, further reducing their carbon footprint. Finally, disposing of robots properly is crucial to reduce their carbon footprint. Proper disposal can involve recycling or repurposing robots, reducing the need for new production of other sources of emissions.

With robots requiring software to be piloted, it is of no surprise that the fully virtual relative of robotics, artificial intelligence (AI), has found similar use in tech. As we see an increase in the use of AI in the workplace, the use of smarter-than-human intelligence raises a plethora of ethical concerns. To combat this, the European Union (EU) has developed a framework for ethical AI, which includes guidelines for the development and use of AI and robotics technology (Madiega, 2019). Under this framework, member states of the EU and their allies have addressed the need for artificial intelligence and robotics to follow a set of ethical guidelines. Notably, the framework includes a set of ethical standards published by the Institute of Electrical and Electronics Engineers (IEEE) which has been adopted internationally by the EU.

Other government entities such as the US, China, Canada, and India among others have also adopted or have drafted similar sets of standards that “largely mirror the EU rules on AI.” Much of the rules outlined in these standards are relatively ethical internationally – with highlights being extensions of Asimov’s Three Laws of Robotics (Salge, 2017) such as the inability for AI and robots to harm humans or disobey human oversight; adoptions of the three pillars of information security and cyber security: confidentiality, availability, and integrity (Cawthra, 2020); and the core principle of a “human-centric approach,” putting humans values first in a way that fundamental rights are respected.

Clearly, regulatory and policy-making bodies have had a significant impact on the development and goals of robot design. Governments and international organizations have recognized the potential of robotics to transform industries and improve productivity, while also acknowledging the potential risks and challenges associated with the deployment of robots. As a result, they have established countless regulations and policies to guide the development and use of robots. Furthermore, regulatory and policy-making bodies have impacted the goals of robot design by establishing intellectual property and patent laws. These laws incentivize innovation by providing legal protections for inventors and companies that develop new robot technologies. Intellectual property and patent laws help to ensure that the benefits of robot innovation are widely shared and that inventors are incentivized to continue developing new and improved robot technologies.

Using the cause-and-effect nature of ANT, a large-scale ecosystem of robots, their creators, regulatory legislature, outcomes of robot use and their relationships to one another has been pulled apart to understand how policy making and regulation has impacted the development of robots. As a result, some of the lesser-known consequences of robot designs have been brought to light. From botnets to employment to idealistic mismatches between the government and the governed, the field of robotics has issues that must be faced through a combination of design changes, policy making, and regulation. While some issues such as the surveillance of people through the use of drones cannot be easily tackled by robot designers and manufacturers, other issues such as the addition of security features for IoT devices rest mostly on the shoulders of engineers.

There is no clear answer to the future of ethics in robotics. Being a new field of engineering, there is little discourse and regulation pertaining to robots. Rather than seeking a single answer, future engineers should instead be mindful of the various consequences of bad design and incorporate strong design elements so that these consequences are mitigated. Furthermore, with the current lack of meaningful legislature, lawmakers must work with engineers to uphold rules and regulations in a way that ensures that robots are not misused.

References

Al-Hadhrami, Y., & Hussain, F. K. (2021). DDoS attacks in IoT networks: a comprehensive systematic literature review. *World Wide Web*. https://doi.org/10.1007/s11280-020-00855-2

Bogue, R. (2014). The future of robotics in Europe. *Industrial Robot: An International Journal*, *41*(6), 487–492. https://doi.org/10.1108/ir-07-2014-0364

Cameron, E. N., & Strasma, J. D. (1979). [Review of *The Mining Industry and the Developing Countries*, by R. Bosson & B. Varon]. *Land Economics*, *55*(2), 285–296. https://doi.org/10.2307/3146069

Cawthra J. (2020). *Executive Summary — NIST SP 1800-25 documentation*. www.nccoe.nist.gov. https://www.nccoe.nist.gov/publication/1800-25/VolA/index.html

De Neve, J.-E., & Ward, G. (2017). *Does Work Make You Happy? Evidence from the World Happiness Report*. Harvard Business Review. https://hbr.org/2017/03/does-work-make-you-happy-evidence-from-the-world-happiness-report

Dizikes, P. (2020). How many jobs do robots really replace? MIT News | Massachusetts Institute of Technology. https://news.mit.edu/2020/how-many-jobs-robots-replace-0504

Environmental Protection Agency (EPA). (2019). *Progress Cleaning the Air and Improving People's Health | US EPA*. US EPA. https://www.epa.gov/clean-air-act-overview/progress-cleaning-air-and-improving-peoples-health

Fruhlinger, J. (2018). *The Mirai botnet explained: How IoT devices almost brought down the internet*. CSO Online. https://www.csoonline.com/article/3258748/the-mirai-botnet-explained-how-teen-scammers-and-cctv-cameras-almost-brought-down-the-internet.html

Gogarty, B. (2017). Backyard skinny-dippers, peeping drones and the law. *ABC News*. https://www.abc.net.au/news/2017-04-26/peeping-drones-backyard-skinny-dippers-and-the-law/8472446

Groover, M.P., Weiss, M., Nagel, R.N., & Odrey, N.G. (1986). Industrial robotics - technology, programming, and applications. CAD/CAM, robotics, and computer vision.

Hassan, A., El Habrouk, M., & Deghedie, S. (2020). Renewable Energy for Robots and Robots for Renewable Energy – A Review. *Robotica*, *38*(9), 1576-1604. doi:10.1017/S0263574719001644

IEEE (2023). *Semiconductor Materials - IEEE IRDS™*. (2023). Irds.ieee.org. https://irds.ieee.org/topics/semiconductor-materials

International Labor Organization (ILO). (2017). *Inception Report for the Global Commission on the Future of Work*. https://www.ilo.org/wcmsp5/groups/public/---dgreports/---cabinet/documents/publication/wcms_591502.pdf

International Labor Organization (ILO). (2022). *EU-Korea Policy dialogue on the future of work*. Www.ilo.org. https://www.ilo.org/employment/Whatwedo/Projects/building-partnerships-on-the-future-of-work/WCMS_835000/lang--en/index.html

Latour, B. (1992). Where are the Missing Masses? The Sociology of a Few Mundane Artifacts. In W. E. Bijker & J. Law (ed.), *Shaping Technology / Building Society: Studies in Sociotechnical Change* (pp. 225-258). The MIT Press.

Lember, V., Brandsen, T., & Tõnurist, P. (2019). The potential impacts of digital technologies on co-production and co-creation. *Public Management Review*, *21*(11), 1–22. https://doi.org/10.1080/14719037.2019.1619807

Madiega, T. (2019). *EU guidelines on ethics in artificial intelligence: Context and implementation* [Review of *EU guidelines on ethics in artificial intelligence: Context and implementation*]. European Parliament; European Parliamentary Research Service. https://www.europarl.europa.eu/RegData/etudes/BRIE/2019/640163/EPRS_BRI(2019)640163_EN.pdf#:~:text=The%20discussion%20around%20artificial%20intelligence%20%28AI%29%20technologies%20and,to%20the%20human%20and%20ethical%20implications%20of%20AI.

Martin, J. (2019). *Eyes in the Skies: The Legality of Drone Surveillance*. Legal Reader. https://www.legalreader.com/eyes-in-the-skies-legality-of-drone-surveillance/

Martinez, R. (2018). *California to Regulate Security of IoT Devices.* Www.jonesday.com. https://www.jonesday.com/en/insights/2018/10/california-to-regulate-security-of-iot-devices#:~:text=On%20September%2028%2C%202018%2C%20California%20Governor%20Jerry%20Brown

Najibi, A. (2020). *Racial Discrimination in Face Recognition Technology*. Science in the News; Harvard University. https://sitn.hms.harvard.edu/flash/2020/racial-discrimination-in-face-recognition-technology/

Ritchie, H., Roser, M., & Rosado, P. (2022). *Fossil Fuels*. Our World in Data. https://ourworldindata.org/fossil-fuels

RSS. (2021). *Maintenance and Repair of Industrial Robots: What You Should Know - Robotic Simulation Services*. https://roboticsimulationservices.com/maintenance-and-repair-of-industrial-robots-what-you-should-know/

Salge, C. (2017). *Asimov's Laws Won't Stop Robots from Harming Humans, So We've Developed a Better Solution*. Scientific American.

https://www.scientificamerican.com/article/asimovs-laws-wont-stop-robots-from-harming-humans-so-weve-developed-a-better-solution/#:~:text=The%20Three%20Laws%20Asimov%E2%80%99s%20Three%20Laws%20are%20as

Salsone, B., Stein, P. S., Parsons, K. G., Kent, T., Nielsen, K., & Nitz, D. T. (2020). Technological Determinism. *Opentextbooks.clemson.edu*. https://opentextbooks.clemson.edu/sciencetechnologyandsociety/chapter/technological-determinism/

Smith, A. (2017). *4. Americans' attitudes toward robot caregivers*. Pew Research Center: Internet, Science & Tech. https://www.pewresearch.org/internet/2017/10/04/americans-attitudes-toward-robot-caregivers/#:~:text=Around%20one-in-five%20%2821%25%29%20feel%20that%20a%20robot%20caregiver

Snow, J. (2021). *How to Build a More Sustainable Robot*. WSJ. https://www.wsj.com/articles/how-to-build-sustainable-robot-11634585544

STMicroelectronics. (2023). *Sustainable Technology - STMicroelectronics*. https://www.st.com/content/st_com/en/about/sustainability/sustainable-technology.html

Welle, D. (2021). *Toxic and radioactive: The damage from mining rare elements | DW | 13.04.2021*. DW.COM. https://www.dw.com/en/toxic-and-radioactive-the-damage-from-mining-rare-elements/a-57148185

Westacott, E. (n.d.). *Moral Relativism | Internet Encyclopedia of Philosophy*. https://iep.utm.edu/moral-re/#:~:text=Moral%20relativism%20is%20the%20view%20that%20moral%20judgments

Willems, J., Schmidthuber, L., Vogel, D., Ebinger, F., & Vanderelst, D. (2022). Ethics of robotized public services: The role of robot design and its actions. *Government Information Quarterly*, *39*(2), 101683. https://doi.org/10.1016/j.giq.2022.101683

Workplace Innovation and Opportunity Act. (2014). https://www.congress.gov/113/bills/hr803/BILLS-113hr803enr.pdf

Young, L. Making of South Korean robot ethics charter: Revised proposition in 2018. (2019). *Artificial Intelligence, Robots and Ethics*. https://doi.org/10.13180/icres.2019.29-30.07.004