Ethical Discussion of Robotic Advancements

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Introduction

The goal of this project is to initiate discussions, explore different perspectives, and provide resources on ethical concerns in the fields of robotics for people to review, think and reflect. This information will be accessible to the general public through a website that any person interested in ethical topics in robotics can explore. After viewing our website, individuals will gain knowledge on primary robotics topics and the related ethical and moral problems behind each of these domains. The viewer will also gain a better understanding of how ethical themes overlap between different robotic domains.

In order to have meaningful conversations about robot ethics, it is important for anyone who is part of that discussion to have an understanding of the technological domain being discussed. It would be incredibly difficult to try and discuss the ethical concerns about surgical robots, for example, with someone who doesn't understand what exactly a surgical robot is, and what potential problems might arise. Additionally, even for people who may have a surface level understanding of a specific domain, there is the potential to discover further information that may lead to a better understanding, or bring up new, undiscussed issues.

This project is important because it can be simultaneously used by people without a technical background and academics in a technical field to get on the same page when discussing robot ethics. Many people may fear the increasing presence of robots in our society without fully understanding the potential benefits, risks, and ethical concerns involved. It is also possible that there are lesser known issues that very few people know about or understand, and bringing them to light would be beneficial. This project can serve as both a starting point for understanding robot ethics in these domains, as well as a springboard for looking further in order to be more well equipped to tackle the issues presented. It can also be a resource for engineers and companies developing robots in these domains to see new ethical perspectives that may have been neglected otherwise.

To realize our goal, we conducted research related to the philosophy of ethics, ethics in the field of robotics, and various robotic domains. Since robotics is a broad field with a wide range of applications, we sorted our findings into a table sorted by robotic domains and ethical themes. In addition to our research, we conducted a survey to gain a better understanding of

people's knowledge, concerns and thoughts towards robot ethics. Having gathered a large pool of information on robot ethics, we decided that a website would be a useful tool to share our findings. The website would serve as an interactive and accessible way for people to learn, get inspired, think, and share their thoughts. We structured the website similar to the table we created for our research, organizing topics by robotic domains and ethical themes. For each robotic domain we include a short story, a background summary describing the robotic domain, discussion questions, and resources for learning more on the topic. The stories are intended to draw the reader in, provide a scenario the reader can relate to or identify with, and give the reader a context to understand ethical questions in.

This report will start with a literature review that details our research on the ethical themes present in eight different robotic domains. Next, the methodology will cover the reasoning behind decisions made throughout the project and how our initial research was used to guide the creation of the website. Finally, the discussion section will reflect on the outcomes of our project, challenges faced, and how the project can be further developed in the future.

Literature Review

In order to effectively start an informed conversation about the ethical concerns of robotics in the near and semi-distant future we first needed to classify the robotic domains. In our research we have identified eight domains that will generate major ethical challenges in coming years and decades: Biomechatronics, Companion Robots, Distributed Robotic Systems, Domestic Robots, Humanoid Robots, Industrial Robots, Military Robots, and Surgical Robots. These domains represent technological paths that will inevitably affect our lives going forward. It is important to initiate conversations about their ethical concerns, so that when facing these challenges we can be proactive to avoid ethical dilemmas and not reactive trying to fix a problem that could have been prevented.

Surgical Robotics

Surgical robots are becoming increasingly advanced and common in the healthcare industry. These robotic systems can be controlled systems which are controlled by surgeons' direct actions, semi-automatic systems which constrain the surgeons movements, or automatic systems which are programmed before the operation (Sharkey 2013). Surgical robotics is especially useful for minimally invasive procedures where it can reduce patient recovery time and possibly increase accuracy and precision (Siciliano 2016). Surgical robots can also be helpful for neurological procedures that require very fine, delicate movements that are difficult for surgeons to perform without robotic assistance (ibid.). While current surgical robotic systems are controlled by surgeons, it is possible that in the future surgical robotics will be fully autonomous. The major ethical themes to consider in the field of robotic surgery include professional responsibility, transparency and explainability, fairness and non-discrimination, and safety.

When a human performs surgery they can be held legally liable for if the surgery goes wrong, if a robot makes a mistake during surgery there is a question of who should be held accountable (Stahl 2016). A robot does not have the capacity for moral reasoning, so how will it deal with ethically problematic situations (ibid.)? A robot cannot be held liable or face legal penalties, so it is necessary to determine which humans are criminally responsible (O'Sullivan

2019). Is the technician controlling or overseeing the robot at fault? How about the company that designed the robot? What about the doctor who recommended robotic surgery to the patient? The answers to these questions are currently being debated and it is important that robots do not be used as a scapegoat by medical professionals (Mavroforou 2010). Furthermore, if an error occurs in robotic surgery, will the robot be able to explain what went wrong? Accountability is defined as “the capacity of a system to give an explanation for its actions" (O'Sullivan 2019). Algorithms used by surgical robots should be explainable so that doctors can check what the robot has learned to prevent the robot from learning incorrectly and to understand the causes of mistakes the robot has made (O'Sullivan 2020).

Surgical robots are often trained using machine learning algorithms which use large datasets to optimize accuracy and precision of the system. While machine learning can be very effective for achieving highly accurate and robust algorithms, it is often difficult to explain exactly how these algorithms work. The algorithm learns based on the training data given to it and if the training data contains biases these biases will become present in the robot’s performance. For example, a robot might be less capable in situations that were rare in its training dataset which may include minority groups, people with pre-existing conditions, or age groups and genders that the specific type of surgery is less common for (ibid.).

It is critical that patients are able to give informed consent before receiving robotic surgery. The patients may be unaware of the newness of the technologies and lack of evidence about its risks (Geiger 2015, Sharkey 2013, Siciliano 2016). The doctor should be able to explain the benefits and risks of robotic surgery specific to each patient (Geiger 2015). Robotic surgery presents a potential conflict of interest; surgeons may be biased towards robotic surgery due to the “career benefits and status of being an ‘innovator’” or because of the investment of training time and resources that the hospital has spent on the robot (O'Sullivan 2020, Sharkey 2013). In many cases robotic surgery could be more accurate and precise than human surgery; however, higher risk patients may not be the best candidates for robotic surgery and “appropriate case selection for robotic surgery should be made to maximize patient outcomes and minimize chances of complications" (Larson 2014). The patient should also be made aware of the financial cost of robotic surgery. New technologies are not always covered by public health insurance and many patients may not be able to afford robotic treatment (Mavroforou 2010).

There are many risks to robotic surgery but there are also many ways the healthcare industry can minimize these risks through organized systems and protocol. Hospitals should "ensure that surgeons have the requisite level of knowledge and experience, the right tools and resources, and a well-trained support staff familiar with the technology" (Sharkey 2013). To facilitate this, there should be an organized system for credentialing surgeons in robotic surgery and surgeons should be required to regularly renew their credentials to ensure they are up to date on the latest of this fast-changing technology (Geiger 2015, Larson 2014). Furthermore, industry representatives from the companies producing these robots should be present to ensure equipment is functioning properly (Larson 2014). Protocols for training and review should also be set to prevent robots from learning inappropriate actions and to review outcomes in an ongoing manner to evaluate safety of the robot (Geiger 2015, O'Sullivan 2020, Sullins n.d.). Finally, surgeons should always prioritize patient safety by selecting appropriate candidates for robotic surgery and switching to another surgical modality or aborting the surgery altogether when needed to maintain patient safety (Larson 2014).

Distributed Robotic Systems

Distributed robotic systems are systems of robots linked through a network, such as the web, for data sharing and cooperative learning and working (Siciliano 2016). Distributed robotic systems can be multi-robot systems in which self-organizing robot teams work in coordination to perform specific tasks (ibid.). These systems can also include networked intelligence systems such as smart cities, which have a mixture of networked devices such as weather monitoring systems, smart street lights, and traffic management systems and robotic systems such as robotic police officers. With robots becoming increasingly advanced, smart cities will likely integrate more robotic technologies in the future.

Distributed robotic systems are becoming further integrated into society as the market for Internet of Things technology, such as Amazon's Alexa or Google Home, grows and Web speeds improve (ibid.). This is a popular field of research because there are many benefits to using a system of many robots working together. Multi-robot systems are more adaptable because they are not designed for one specific task (Kagan 2019, 13) . They are also more reliable because if one robot becomes damaged, the rest of the system remains intact. They are also very useful for

large scale applications because a system of multiple robots can spread out across an area to sense and act over a larger space. While an individual robot can only gather information from its immediate surroundings, robots that are part of a system can access information from its own surroundings as well as the surroundings of other robots in the system. An example of this is military microdrones which communicate with each other on intelligence gathering missions (Tarantola 2020). Despite the usefulness and convenience of distributed robotics, there are many ethical concerns associated with these systems including privacy, security, transparency, fairness and non-discrimination, and identity.

Networked intelligence systems and distributed robotic systems collect massive amounts of data and it is difficult to give notice and get consent for data collection when citizens are interacting with a large number of data collection devices on a daily basis (Kitchin 2016). Even when consent is obtained, it "often consists of individuals unwittingly signing away rights without realizing the extent or consequences of their actions" (ibid.). While the data collected can be used in ways that benefit citizens, such as the smart city technologies intended to improve quality of life of citizens, it can also be a threat to free choice and civil liberties. With this data in the hands of large corporations or a corrupt government, "human rights organizations are legitimately concerned about mass surveillance as a threat to civil liberties. A corrupt government can get to know your every move, habit, medical problem, and other private details" ("Ethical issues of smart city" 2020). It is important to have consent and transparency data collection; however, it is also crucial for the consumer to be educated on the risks of data collection.

Systems containing large amounts of data will be targeted for cyber attacks. While companies put effort into making their technologies secure, there is always a risk of a data breach or cyber attack; "preventive measures alone are not enough for dealing with adversaries" in cyberspace (Rehberger 2020, 1). Large companies including Apple, Amazon, CVS Health, and many others have faced data breaches in recent years (Haqqi 2021). In addition, some companies or governments may take shortcuts with regards to security to save time or money and "some government systems are simply corrupt to the point they cannot guarantee decent protection of their citizens' personal data" ("Ethical issues of smart city" 2020). Especially as

society becomes increasingly dependent on these networked technologies, it must be considered how a cyber attack would impact communities (Kitchin 2016).

Robotic police forces have also been introduced in recent years as part of smart city technology. On one hand, robotic police forces without the use of algorithmic profiling could present an opportunity to reduce biases that are present in a human police force. However, many robotic police systems rely on machine learning algorithms for profiling ("Ethical issues of smart city" 2020). Since the datasets used for training the robotic police force come from an already biased law enforcement system, these biases will also be present in the robot; "in 2016, a coalition of US civil rights organizations picked predictive policing apart with a joint statement describing the technology as 'biased against communities of color'" (ibid.). The use of data for profiling or grouping people can also lead to deindividualization.

> "When group profiles are used as a basis for decision-making and formulating policies, or if profiles somehow become public knowledge, the individuality of people is threatened. People will be judged and treated as group members rather than individuals" (Van Wel 2004).

In any case where data is used to train an algorithm, it is important to examine what features the training is using to group people, analyze what biases may be present in the dataset and form a strategy to limit these inequalities.

Companion Robots

In developed countries, especially Japan and the United States, aging society is getting severe, and other countries in development tend to face the same issue. The elder caregiver will be in a significant shortage shortly (Jason 2019). Companion robots can be an effective solution to this problem. Companion robots already exist, and some of them have been used in care settings for more than a decade in multiple countries (Hung 2019). It turns out Companion robots are more difficult for the public to accept them than people thought (Johansson 2020).

Use the most discussed elder robots as an example. Their primary target, the elders, has a hard time accepting the Companion robots. They have more negative feelings taken care of by robots (Johansson 2020). According to the research, the elders feel they are losing their rights.

Privacy is hard to be guaranteed if we want robots to help elders to keep them safe (Sharkey 2012). Should the Companion robots follow, monitor the care recipients at any time, including in the shower or bathroom? Reporting care recipients' activities and location to their families and doctors might also invade privacy. How could we find a balance between the care recipients' rights and safety? Another reported problem is that the care recipients feel that they are losing control and independence of their lives (Sharkey 2012). Getting arranged by Companion robots means the care recipients might lose the autonomy of their own lives, which in research makes care recipients feel uncomfortable (Sharkey 2012). To ameliorate this problem, increasing care recipients' autonomy can be an effective way. Indeed, Companion robots are proved helpful in the prevention of depression and dementia (Hung 2019). The precondition of that is that the care recipients are willing to interact with Companion robots. However, individuals might feel embarrassed interacting with Companion robots, especially males, or in front of other people, significantly influencing their performance (Hung 2019). On the other hand, some positive results show that human caregivers or nurses might make care recipients lose dignity at some embarrassing scenes, like changing diapers. Companion robots do not make care recipients feel the same way, which can be advantageous compared with human caregivers (Sharkey 2012). When building emotional connections with Companion robots, deception and infantilization can also be a problem. To interact and communicate with Companion robots, the care recipients must periodically deceive themselves into believing what Companion robots say is true, even if they know robots do not have feelings. Some people view this as infantilization for asking them to make friends with robots (Sharkey 2012). Based on that thought, some people believe Companion robots cannot give true care. All those emotional connections with Companion robots are just built on deceptions, which might increase the care recipients' loneliness and isolation (Wachsmuth 2018). According to the research, the visits from families decrease after the care recipients are cared for by Companion robots (Johansson 2020).

In sum, there are many promising potentials in Companion robots, but also related problems we need to think about. How to maximize the benefits of Companion robots and minimize the ethical issues can be a challenge we need to solve. Increasing the autonomy of care recipients, letting the care recipients--not the families nor the doctors--control the Companion robots, and listening to what care recipients need can be a good start.

Humanoid Robots

The humanoid robots are robots whose body shape and face resemble the human appearance. Due to that feature, the humanoid robot is one of the most controversial topics in robot ethics, and it has been the heated discussed topic in many fiction novels and movies. People always think about how a society coexisting with humanoid robots will be like and how to solve the potential ethical issues. Before discussing the ethical issues of coexisting with humanoid robots, we should think about why we even need humanoid robots first. Some people believe that humanoid robots are just the wrong answers to the right problems, and robots that look like humans are immoral and creepy (Ryan 2019). In the future, humanoid robots have an immense chance to be integrated into nearly every aspect of our lives, including public education to privatized uses such as interacting with children. When we get along with humanoid robots and even build emotional connections with them, how can we differentiate between robots and humans since they look so similar? It is a hard question even for an adult, let alone children whose cognitions towards this society and intimate relationship are still developing. How can we correctly lead children to build healthy relationships with humanoid robots? The appearance of a humanoid robot can be confusing for a child. According to the research, the younger a child is, the harder it is to tell the difference between a humanoid robot and a human (Kahn 2012).

Another problem when we talk about coexisting with humanoid robots is human rights. If we endow humanoid robots with human rights, we have no active rights to rule over the robots and treat them like slaves (Stephy 2019). If we educate people that humanoid robots should not enjoy the same rights as humans, are they accountable for their mistakes because of the wrong program? Humanoid robots' sensation or perspicacity can be a crucial point to help us decide when it comes to rights and accountability. In contrast, we do not want to build humanoid robots with sensation, since part of the reason why all robots exist is to build a better human society and replace humans to do dangerous work (William 2011). As long as humanoid robots are self-aware of their existence and obtain equal status as humans, we can not use robots and ask them to work for us anymore because it invades the rights robots enjoy (Stephy 2019). However, it is challenging to guarantee that robots without a complete understanding of human emotions will not harm other humans since they lack empathy. As a result, people should not expect humanoid robots to protect humans unconditionally if they have complete autonomy. They can not

understand humans' emotions without sensations as well. As a result, rules will definitely be needed to guarantee humans' safety. Besides physically hurting people, which can be easily prevented by programming or set the rule, humanoid robots without sensation can cause other problems. According to the research, robots' involvement in business can ruin the trust between the people involved in traffic as automation tends to ignore the vital aspect of human interaction, such as morale, to maximize profit (Nicholas 2019). As a result, if we live in a society getting along with humanoid robots, one of the most important things is building the corresponding rule or law for humanoid robots to obey. Society should clearly understand the differences between humanoid robots and humans and have different expectations towards them.

Last but not least, we should discuss who is responsible for the outcome (either bad or good) caused by the robot's action, either by order or autonomous action. According to the research, most people believe that humans, like programmers or manipulators, should be more accountable than humanoid robots (Peter 2012). The government and the expertise should make up a sound law, from restriction to accountability, to prevent the potential risk. However, some people also think if we treat humanoid robots and humans differently, we are legislating discrimination (Stephy 2019). It is both the professional and government's responsibility to find a balance in between. Generally speaking, we still have a long way to build a coexisting society with humanoid robots. Hopefully, by then, we can find a better approach.

Biomechatronics

This more recent robotic domain is characterized by the integration of mechanical and electrical technology with biological organisms in an effort to improve and/or expand biological functions. Development of this field seems to follow at least one of two trends, to use biomechatronics to eliminate disability (E&T editorial staff, 2020) and to expand the senses of the human body (Harbisson., 2012). These avenues of technological progress open ethical lines of questioning for the biomechatronics domain. The ethical themes that primarily show for this domain are human rights, identity, human control of technology, fairness and discrimination, and last but not least government.

Using biomechatronics to eliminate disability primarily started with the creation of more advanced prosthetics that bridged the gap between traditional prosthetics and what we know

today as biomechatronics. A great example of this and a leading researcher in biomechatronics is Massachusetts Institute of Technology Professor Hugh Herr. Herr lost both of his legs while climbing Mount Washington and soon after committed to developing high grade biomechatronics for other amputees and other devices to help eliminate disability (Kirby, 2018). Opening up this path of development links the domain with the government as well as fairness and nondiscrimination ethical themes. With the goal of eliminating all disabilities possible with biomechatronics the technology must first overcome some challenges. The integration of new medical devices into the current medical field is no easy task, for biomechatronic procedures to become available to everyone government and medical organizations must develop regulations and procedures asking questions like when will the devices be considered to be needed? Or is it immoral to deny biomechatronics to someone even if they don't need them to survive? Currently biomechatronics are obtained primarily through people who seek out and pay large amounts for the technology, but Herr has already begun presenting research to Centers for Medicare & Medicaid Services to get the devices to all patients who need them (Johnson, 2014).

Although biomechatronics have great applications in the medical field, they are not reserved for only eliminating disability. People have begun to get biomechatronic implants that expand the capabilities of their body. A simple example are radio frequency identification chips (RFID) people get in their hand in order to eliminate the need for credit cards, keys, or even identification cards. A more drastic example is the story of the cyborg artist Niel Harbisson. Being born color blind Niel Harbisson was not going to let that keep him from perceiving color, he got a biomechatronic brain implant that associated colors with tones he hears when the camera attached to his implant is pointing at something (Harbisson, 2012). This implant, although at first created to eliminate color blindness, could then easily be adapted so that the cyborg artist could perceive color outside of the human visible spectrum, allowing him to extend a sense past that of human capabilities (Harbisson, 2012). This path of innovation opens the domain up to the identity and human rights ethical themes. This type of use of biomechatronics allows everyday people to improve and even add functions to their body for convenience, practicality, and self expression. Trying to develop regulations for what type of biomechatronics people should have access to becomes more difficult in this area. Who is to say what body augmentations to their own bodies out of self expression? That being said there must still be

some type of regulation to prevent people from getting biomechatronics that could purposefully or accidentally hurt themselves and others.

Despite their differences, both avenues of development connect the the ethical theme of human control of technology. Either way this level of integration of technology with the human body has not yet occurred. How will making robotics an extension of ourselves effect how we interact and view all technology? Biomechatronics will not only change how we use technology, but make it become a part of us. This will change how we interact and view all technology as we further integrate robotic systems with our own biology.

Domestic Robots

Domestic robots, also known as household robots, are automated devices used to improve one's homelife, usually by doing chores like cleaning. Modern domestic robots, like the Roomba, don't spark much inquiry into ethical concerns but as the field evolves we must be ready to face issues within the ethical themes of accountability and safety and security.

Domestic robots, like living creatures, can either be specialists or generalists. Current domestic robots are mostly specialists (Homigold, 2018). Take the Roomba, it was designed to do a single thing, vacuum the floor, and even with that single purpose it is still limited to a single floor and by its incapability to learn and improve upon its function. Generalist domestic robots are widely thought of as the future domestic robots. They are able to complete numerous tasks autonomously and learn how to better complete them for the individual household. These robots are usually thought to be humanoid so as to make them more familiar to people as well as ease of movement throughout the house. These features make generalist domestic robots sound like robot butlers from the future, but robots like this already exist (Homigold, 2018). Honda’s Asimo robot is a humanoid generalist robot first introduced in 2000. The robot has auditory, visual, and tactical senses of a person and is able to use information gathered from its surroundings to determine the best possible course of action (Honda, 2011). This allows Asimo to not only think and interact with its environment, but people. The robot is able to keep track of a conversation, predict movement patterns to avoid interfering with others, and even has alternative forms of communication such as basic sign language (Honda, 2011).

As generalist domestic robots become more common we must start conversations within the ethical themes of accountability as well as safety and security. Accountability is a major factor for generalized domestic robots in more than one way. One way it comes into play is who is responsible if the robot makes a mistake or malfunctions causing the damage to a person or their property? Current liability law is quite flexible and might be able to settle the first few disputes, but as technology evolves and the robots become more adept at learning and to modification from owners it could become harder to pinpoint who blame for an incident lays upon (Ebert, 2020). Safety and security play a larger role on the corporation side of producing the robots. If there is a robot constantly monitoring your home and learning from the people and environment within, companies must make sure that customer data is safe as well as make sure no one could use a domestic robot to harm anyone else. This could prove to be difficult as data miners and do it yourself (DIY) modifications become more commonplace with more people taking advantage of vulnerabilities in technology.

Industrial Robotics

Industrial robotics, given that they are extensively used and have a palpable effect on the population, are brought up often, particularly in regards to the job displacement that automating the work force brings. While, as a whole, this issue is indeed important, there are other aspects of the problem that are lesser known, and bringing awareness to these complexities can aid in understanding the effects of industrial robotics as a whole, as well as bring to light how these issues overlap with others.

For example, while displacement can affect a wide variety of people, especially as automation gets more and more advanced, and more capable of completing a wider gamut of tasks, marginalized groups have the potential to be disproportionately displaced compared to others (Brussevich, 2019). Certain groups of people may be more likely to get jobs that can be easily automated, meaning that that group is affected by the automation of their field more than others. While displacement is an issue that can affect many, it compounds with other issues and creates intersections where people are affected more than others.

Despite this, studies show that people find layoffs due to automation to be more fair than those caused by outsourcing, or in general that it is more fair when a worker is replaced by a

more efficient worker, automation included (Wakslak, 2019). Additionally, while automation does indeed cause a "direct displacement effect" which lowers labor demand, there are additional forces which work to counteract this, such as reducing the cost of production as well as further improving already automated tasks (Acemoglu, 2018).

Those replaced by an automated workforce may have the potential to seek employment in fields created or expanded upon with an increase in automation. In the case of Artificial Intelligence, many new types of jobs will potentially become quite commonplace, such as Trainers, who aid artificial intelligence in learning things like sarcasm for example, or to help reduce bias that might be inherent. Other types of jobs include Explainers and Sustainers, who work alongside AIs, coordinating the use of them as well as their integration into current work (Wilson, 2017).

Military Robotics

Due to the nature of military research, and the kind of publication that surrounds war, it can be difficult to identify what is actually current and relevant, especially given that some things may be classified or not well covered. It would be hard to discuss the potential ethical concerns and issues surrounding a topic when one does not understand the topic well, and so it is important to give a good idea of what is currently capable in military robotics, as well as where it might lead.

Understanding what is possible in the field at the given time is important since this is one area in which it is key to be proactive, with establishments such as the Geneva Convention setting rules in place before they can become an issue (Bowcott, 2015). Giving a couple of examples of the robotic systems currently being used in the field gives a better idea as to what things might be an issue in the future, in addition to what things may already be an issue.

The morality of military robotics is also very complex given that war in general is a very morally grey area (Hellström, 2013). One's opinion on automation in the military could vary greatly depending on what they believe about war in general; One person may have no qualms about a machine with the agency to take a life, while another may already have issues with a person taking another person's life. In any case, facts about how military robotics might perform,

their advantages and disadvantages, as well as other useful information would allow someone to better form their own opinion on the technology as opposed to being less informed (Brown, 2007).

Methodology

Background Research

As technology continues to advance, robotics is extending into an increasing number of applications and fields becoming further integrated into our everyday lives. To understand and show the scope of ethical concerns in the field of robotics, we determined our first step would be to develop a table that showed the intersections of the robotic domains and ethical concerns. The table would use our robotic domains and ethical concerns as axes and each intersecting box would give an overview of how that technology is connected to that ethical theme. To do this we needed to begin with more broad and general research before narrowing down to specific robots or robotic domains. In order to widen our understanding of robotics and their ethical concerns we first examined possible future scenarios in Illah Reza Nourbakhsh's *Robot Futures* 2013. The book provides analyses of possible issues brought about from the development of robotic technologies in the future. Throughout the first phase of our project our team read chapters of *Robot Futures* and then individually created concept maps to visualize and more easily discuss what we found to be important or related to each technology and underlying issue. Using this resource our team was able expand our knowledge on the ethical concerns and future implications of robotic technologies and were beginning to find ethical themes that stretched between robot domains. Ethical themes like human rights, safety and security, government, and accountability were prevalent in many robotic domains and were easier to distinguish as these are themes apparent in many ethical issues that we currently face. However, in order to gain a deeper understanding on general issues surrounding technology ethics, we examined philosophical theories and concepts inVal Dusek's *Philosophy of Technology: An Introduction* 2006. After this initial research, we added the ethical themes of transparency/explainability, fairness and non-discrimination, identity, human control of technology, professional responsibility, promotion of human values/ public interest, and anthropomorphization. While we

benefited from future projections in *Robotic Futures*, we realized that we need to determine technological domains. We thus turned to Bruno Siciliano and Oussama Khatib's *Springer Handbook of Robotics* 2008, an authoritative text on robotics and different application domains. When choosing our domains we discussed how different subfields of robotics fit together and determining how each is distinctly different in use and ethical concerns. This was all to ensure that there wouldn't be much overlap in content between domains so each section could be unique and discuss a different topic.

Once our team had determined what our ethical themes and robotic domains would be we were able to start filling in our table. At the start we used the intersections between the two axis to organize topics and questions we had for each combination of ethics and technology. This would then act as our starting point to further research each section. While filling out the table we noticed that some intersections didn't seem very strong or didn't work entirely. For example, biomechatronics doesn't fit with the ethical theme of anthropomorphization since biomechatronics is the integration of robotic parts into the human body, so how could it be humanoid? Finding these gaps in our chart was a great insight into the dynamic of our technologies as well as starting the change from creating a table to a website detailing all robotic domains and their ethical themes individually. This transition was brought forth even more once our team started to do research into specific technologies. We quickly found the vast amount of information we wanted to convey would not fit into a table. With this realization we decided the table would take the form of a gallery of the robotic domains and ethical themes with short excerpts describing the section that linked to more in depth pages on each.

Survey

To better understand the tech students' perception of robot ethics and concerns regarding moral issues brought by robot development, we decided to conduct a Robot Ethics Lab questionnaire and asked how students who study in a tech school consider some potential moral questions related to robots. The reason why we chose questionnaire as the survey tool is that questionnaire is more cost-efficient compared with other survey tools like interview. Moreover, online questionnaires can automatically compile collected data and display simple visualisation like pie charts (Jones 2013).

Our survey is approved by the Institutional Review Board (IRB), a committee that guarantees the participants' rights, welfare, and privacy as it contains human subjects. This survey is anonymous and targets both undergraduate and graduate students of Worcester Polytechnic Institute (WPI). The participants need to be 18 or older to respond to this survey. With the consideration of the IRB request, we decided not to include minors as our survey subjects, which can guarantee to minimize contained risk. Also, out of practical reasons, it can be challenging to monitor our survey subjects' demography. As a result, we decided to limit our survey participant pool to WPI students. Most WPI students are majoring in engineering, which ensures some engineering background. We include some explanation of professional robot terms in our survey, but participants with engineering backgrounds can decrease the rate of misunderstandings by any chance. In the end, we sent out our survey through group chats or emails in different greek organizations, school clubs, majors, and other personal connections in WPI.

The survey had sixteen questions in sum[See Appendix B]. The first three questions are about the participants' educational backgrounds and whether they have ever interacted with robots. Those questions allow us to acknowledge the respondents' general background and demography in such a way that we can better analyze the survey results. The fourth question is about the selection between privacy and the convenience brought by robots. Privacy is one of the primary issues with the development of technology. We would like to know the participant's opinions and choices between human rights and the benefits of robots. We describe this question with a scenario, which allows the respondents to put themselves in the situation and provide more considered answers. The fifth question generally asks people's opinions between humanoid robots and robots without human appearance, and the sixth question is related to biomechatronics. Both humanoid robots and biomechatronics are subfields in our research. We believe that it is inevitable for humanoid robots and biomechatronics will undergo similar controversies as they share similar external aspects with humans. Our goal here is to figure out how people would react once they interact with these robots. Question six introduces the background of body augmentations, which enables people who are not familiar with biomechatronics to gain more understanding of the situation. From question seven to question nine, we ask the participants' opinions on controversial moral concerns such as taking human jobs, building emotional connections with robots, and the general risk with robots. Those

questions are common concerns in modern science fiction movies or novels. For instance, In science fiction, they often portray the robots' negative side with the concerns I elaborated in this paragraph. However, we wonder whether the participants believe the same way as science fiction works present and how severe and influential people believe those concerns can be, which can help us better understand the participant's view on those heated ethical topics. Questions ten to twelve are three opinions and concerns with value judgment, and we want to know the extent to which the participants agree. We brought up question thirteen to see the ranking of main concerns toward robotics ethics in participants' views. The last three questions are open questions. We wanted to know some other concerns they may have towards robot ethics besides those controversial worries we have mentioned.

Website

When discussing the end goal of our project, one thing we kept in mind was what we wanted our research to be going towards, and how we could most effectively share this information. We wanted to do something that would be both accessible and as extensive as the research we had done and would continue to do, having options for both people who knew nothing about the particular topics at hand, and people who were already well versed, as well as those in between. We came up with a few ideas, ranging from a storytelling game to a written 'guide' on Roboethics as a primer for those who were not familiar, but eventually decided on making a website.

A website allows us to have a wide array of information, giving users the opportunity to start looking into topics where they are comfortable with the information, and then learn more as they explore the site further. Theoretically someone would be able to, with only some technical literacy, go from not understanding what a surgical robot is to understanding some fairly complex ethical concerns in the topic, to potentially even coming up with possible solutions on our own. Someone who already knows about what a surgical robot is would not have gained much from an explanation of what a surgical robot is, but they would still get value out of the progressively more in depth information. Even someone who is an expert in the field would be able to engage.

We decided that the website should be organized in such a way that the main content of the website would be the most accessible, that being the stuff that requires the least amount of background knowledge to understand, and then from there one could browse the website further to find more information that builds off of that knowledge. To that end, the stories and brief technology descriptions of the technological domains are the foremost portion of the website, and the majority of the work for this project went towards these stories.

Each technological domain features its own page, in which a short explanation of the domain is preceded by a fictional story that is meant to put the reader in the shoes of someone that is facing a dilemma caused and/or about the technological domain. Once the reader has been painted a picture of one possible scenario that relates to the domain, they are given a brief, more technical description, followed by a series of questions.

These questions are designed to be open-ended, and to get the reader to think more on what they have just read and learned about as a potential primer for future discussion. Additionally, these questions do have an ‘answer’, that is either one possible solution of currently held opinion about the question, however these are hidden at first. The reader is intended to read a question, think about it for themselves, and once they have made their own mind up about it, they can then view the quoted answer/opinion to see how their stance differs. Following these questions are the sources, which also give the reader an opportunity to look further into the topic by reading primary sources if they so wish.

Each of these pages has a comment section as well, so that users can post their own questions related to the domain, answer the questions of others, or simply state their opinion. We believe that a comment section would be beneficial to those who are interested, since they can see the opinions or understanding of more people than with the stories and questions alone.

Aside from the stories, there is also a navigation page for the technological domains with an included gallery that gives more examples of each of the domains visually. Catering to those who would like to ‘go deeper’ than the stories, questions, and discussion, we also have a way to navigate and display the intersections of our technological domains, and specific ethical concerns. One such intersection might be the concerns related to the Humanoid Robots technological domain, and the Government ethical domain.

Stories

When discussing how our team would present the robotic domains and ethical themes our priority was to make sure that the information was beginner friendly to people who were not extremely familiar with robotics or ethics so that they could start to be a part of the conversation. To do this we thought it would be crucial to have an element on each page that people could relate to and use to better understand the technology and ethical concerns. We ultimately decided that a short narrative story for each domain and its themes would be the best way to introduce people to each page of the robotic domains. These stories would allow readers to connect with a character as they face ethical dilemmas surrounding robotics and give the team something to ground and relate ethical questions to. To make sure the narratives were effective we needed to understand the basics of ethics education. Stephanie J. Bird and Joan E. Sieber's *Teaching Ethics in Science and Engineering: Effective Online Education* 2005 states that, "...case studies may be used in science and engineering ethics courses to enable students to engage in effective ethical analysis and problem solving…" (326). This confirmed that the narrative stories acting as a point of interest would help readers engage in ethical analysis. However, actually writing narrative stories for each domain set its own challenges. First and foremost, since our goal is to educate people on these technologies and concerns we had to be sure to remain unbiased in our stories and allow our readers to form their own opinions on the issues at hand. To circumvent biases from entering the stories with each iteration our advisors checked our writing, and before finalizing our stories our whole team read through each story individually and then came together to ensure no bias made it to the final draft of the stories. Letting the reader draw their own conclusions is also why stories were left open ended. We want the reader to determine what they believe should happen based on the information presented. This helps with starting the conversation of how these issues should be handled since we are not giving our rendition of what we think should or would happen in these scenarios. Each story is also accompanied by a year to give an estimate as to when these ethical concerns might start to affect everyone. We felt this was important to include with each story as it shows the reader that they could face these ethical implications within their lifetime and drive home how important it is to understand the technology that will directly affect our lives.

Discussion

Background Research

Our initial background readings, research, and discussions gave us insight to which ethical themes and robotic domains would be most relevant to explore further. While reading Illah Reza Nourbakhsh's *Robot Futures*, we created concept maps which map concepts and their relations to one another. *Figure 1* below shows two examples of concept maps created for *Robot Futures* chapters 1 and 5. By breaking down each chapter into only a few concepts, we were able to identify the most important themes in the chapters. For example, in the maps below we found themes of privacy, accountability, identity, and government, all of which we included in our table at the next stage of our research.

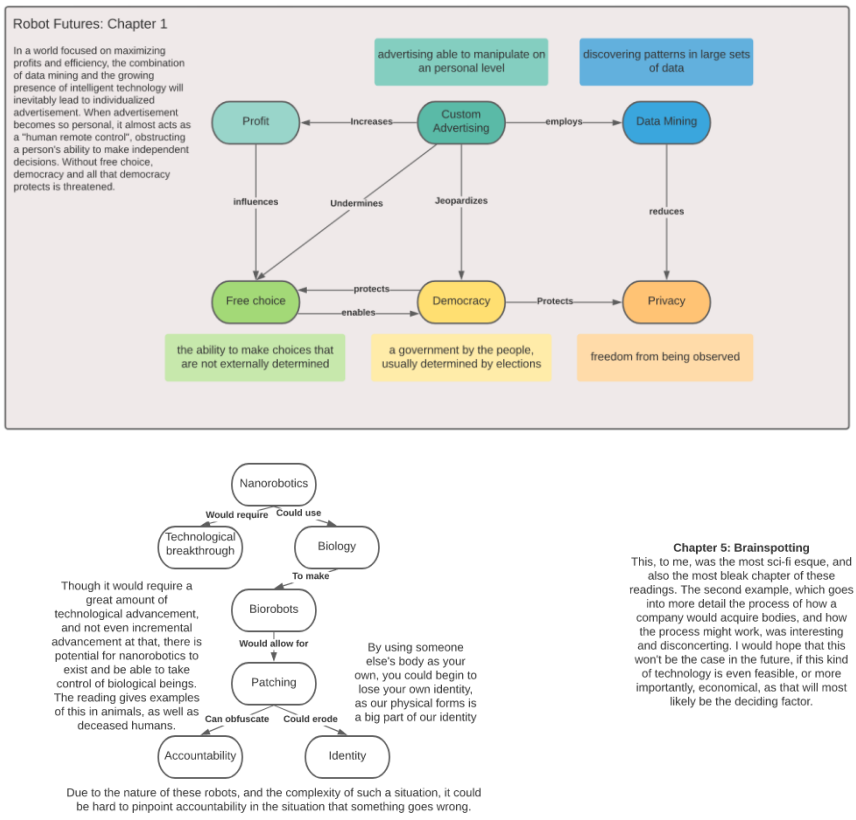

Figure 1: *Concept maps of Robot Futures Chapters 1 and 5*

Guided by the common themes found in our concept maps and the robotic domains we read about in *Springer Handbook of Robotics*, we created a table with one axis for ethical themes and one axis for robotic domains. At the intersections within the table we included ethical questions that addressed a specific ethical theme within the corresponding robotic domain. Our final table included the following robotic domains: humanoid robots, industrial robots, domestic robots, distributed robotic systems, outdoor robotics, biorobotics, biomechatronics, healthcare robotics, military robotics, robot entertainment, and robot companions. On the ethical themes axis we included the following categories: human rights, government, accountability, safety and security, transparency and explainability, fairness and non-discrimination, religion, identity, human control of technology, professional responsibility, promotion of human values and public interest, and anthropomorphization. The table covered a wide range of concerns and robotic topics and although all the ethical questions put in the table could evoke important discussions, we needed to narrow our focus to have a feasible number of topics to research in more depth. We picked which robotic domains to explore further by choosing the domains that bring up the most ethical concerns and issues that are unique from other domains. The detailed research for each of our chosen domains is presented in the literature review and each domain has its own page on our website.

Survey

In the Robot Ethics Lab survey, we received twenty results at the end. Because we set the survey target to students in Worcester Polytechnic Institute (WPI), 95 percent of the participants answered that they received some college or higher education. Eighty percent of participants have interacted with robots in real life; the rest of 20 percent have heard about robots in real life or online. This result is expected since WPI provides the robotics engineering major for students to study. The types of robots they have interacted with mostly are domestic robots, robots at school for educational purposes, or combat robots in competitions.

From question four, the survey hears people's opinions instead of background anymore. It turns out, in some fields, people are more conservative towards the changes brought with robots. When there are conflicts between the benefit brought by robots and people's privacy, most people (65 percent) will not buy a robot that might leak their private information even if the

robot can improve their lives. When it comes to humanoid robots, only 25 percent of participants agree that robots with human traits will benefit society more than robots without human traits. More people (40 percent) are neutral towards the benefits of humanoid robots. Biomechatronics turns out to be more acceptable than humanoid robots. Eighty-five percent of participants believe that people should be able to augment their bodies as they see fit, and only 5 percent of people disagree with it.

Regarding the moral concerns that robots might bring, the participants are more optimistic than expected. Participants think robots are more like auxiliary methods instead of solutions in the future. Only 20 percent of people believe that robots can fully replace doctors and teachers, and 5 percent believe robots can fully replace doctors but not teachers. Most people (70 percent) believe that robots will assist but not replace doctors or teachers. None of our participants think the potential risks of robotics outweigh the potential benefits. Seventy percent of people think robotics' potential benefits outweigh the potential risks, and 30 percent of people are neutral. Concerning emotional connections with robots, 45 percent of participants think humans will have emotional connections with robots. Fifty percent of people believe emotional connections with robots depend on the appearance and the utility of robots. Only 5 percent of people believe that humans will not have emotional connections with robots. People who are worried that robots will invade privacy and people who are not are about the same amount. In science fiction movies, there are lots of plots about artificial intelligence becoming more intelligent than humans. It turns out people worrying about robots becoming too smart is about the same amount as people who do not. However, people have more concerns about robot hacking in our survey result. Only 25 percent of people are not worried that robots being hacked will influence society.

Among all the concerns related to privacy, cybersecurity, robots surpassing human intelligence, military robots, and robots taking jobs, cybersecurity and military robots are voted as most concerning. Privacy has the evenest pattern; people hold different but not extreme opinions towards it. Regarding robots surpassing human intelligence, the voting pattern presents to be the most extreme; many people vote it as the most concerning, while many other people vote as the least concerning. Robots taking jobs is the least concerning issue overall.

In respect of non-fictional robots' moral concerns, outdoor drones, military robots, autonomous vehicles, and artificial intelligence are the most common concerns to our participants. Many direct reasons they are worried about are that they believe those technologies have risks on humans' security. In respect of fictional robots' moral concerns, artificial intelligence and robots authorized to kill humans are the most mentioned worries. Some people specifically show their concerns about the cyber hacking attacks as well.

After viewing and analyzing the survey result, we gained an understanding of how the public, especially people who are majoring in engineering, perceive robot ethics. Moreover, we understand their major concerns about robot ethics and the reasons behind them. Granted, there are some limitations in our survey results. The survey results might be more biased than realistic since our participant pool only includes students in WPI, which might not represent students in other tech schools. Our participants might also include students whose major is robotics engineering or other robot-related fields. Staying in related areas might make them have more optimistic or conservative opinions towards robot ethics.

We utilized our survey results in the website we built, and the results provide statistical support for our website contents. We also introduced our survey results in the website's fields pages so that the visitors of our websites can also acknowledge people's concerns towards each specific field.

Stories

During the process of coming up with and writing our stories, we each ran into a few issues that were common amongst all of us, as well as things that pertained to our area of discussion specifically. One common issue was trying to develop the stories in a way such that as many issues as possible were brought up without them being forced, striking a balance between making the story more multifaceted and also preventing it from becoming convoluted. Since the stories are the introduction to the topics, it would be beneficial for them to give as ‘wide’ a view as possible, however we typically had to limit the amount of topics in our stories to keep them coherent.

Another issue that was common was the fact that there needed to be a balance between how realistic or plausible the story was, as well as the impact that it had. A story that is entirely realistic, or what would be the most plausible sequence of events possible might also be very boring, or would not engage a reader enough, while a story that is over the top or exaggerated might certainly get the reader's attention, it might be completely unrealistic. This was especially difficult considering many of the issues we bring up in these stories are not issues that currently exist, and may potentially never exist. Since these stories are meant to be in the future, we can only predict or presume what may or may not be the case.

While writing these stories, we also needed to discuss to what extent we wanted to diversify these stories, as we knew we would have to pick stuff within our 'comfort zone' to depict so that we did not unintentionally step on any toes. However, because of this, these stories may not be as diverse as they had the potential to be.

However there were also problems that were specific to the domains of the stories, either due to the domain itself or the ethical concerns that were brought up in those stories. For surgical robotics, one such issue was that the current surgical robotics technologies do not allow for complete autonomy, which is where things get more complicated in terms of ethical analysis. The story assumes that in the future, fully autonomous surgery is relatively commonplace, which allows for further ethical analysis of the possible issues it might cause. One issue with writing the distributed robotics systems story is that the example given is a smart city, however many if not most of the components of a smart city are not actually robotic at all, which is a problem if we are focusing specifically on roboethics.

With industrial robotics, discussing solely the topic of job displacement without any other factors would not give a particularly in depth look at the possible issues in the domain, given that job displacement as a whole has been looked at extensively. An issue very specific to military robotics is that it can be difficult to depict war in a way that is unbiased while also being specific enough for the story to work.

When coming up with the story of humanoid robotics, it is significant to pick the story's scenario. Due to the nature of humanoid robotics, it can be applied in multiple different areas. In the end, we picked a story that the humanoid robot interacts with children because there is

already research and experiment discussing how children perceive humanoid robots. Basing on current research can help us to come up with a more realistic story. Also, since this story happens at home, we need to differentiate humanoid robotics from our other topic, domestics robots. As a result, when describing the story and potential issues, we focused more on how robots' human traits influence children. For companion robotics, elder caring robotics is currently becoming the most promising robot type among all companion robotics. Especially in Japan and the United States, a few retirement homes already applied companion robots assisting care-givers. Those issues we brought up are real problems at the beginning stage of utilizing elder care robots. To make the story more impactful, we narrate the story from the care recipient's angle because we want the readers to consider the potential concerns care recipients encounter.

Conclusion

Appendix A - Stories

Appendix B - Survey Questions

Appendix C - IRB Approval

Appendix D - Bibliography

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