A CODE OF ETHICS FOR ROBOTICS ENGINEERS

An Interactive Qualifying Project Report

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Abstract

This project developed a draft code of ethics for professional robotics engineers by researching into the fields of robotics, ethics and roboethics to develop the necessary understanding. The code was drafted and presented to students, professors and professionals for feedback and revision. The code is now hosted at the Illinois Institute of Technology's Center for the Study of Ethics in the Professions website (ethics.iit.edu), and is open for discussion at (rbethics.lefora.com). It is being proposed for adoption to the WPI Robotics Program faculty and the WPI Robotics Engineering Honors Fraternity, Rho Beta Epsilon.

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Introduction

There currently exists no governing body devoted solely to professional robotics engineers, nor a code of ethics to govern their behavior. Robotics engineering is a rapidly growing field with many unique aspects that will undoubtedly lead to ethical situations not addressed in existing engineering ethical codes. These unique aspects mainly arise from the characteristic ability of robots to judge an environment and act on those judgments, a capability unique to the products of robotics engineers. In order to address these unique facets of robotics engineering, a formal, written code of ethics was created with similar goals to those of the Institute for Electrical and Electronics Engineers (IEEE), American Society of Mechanical Engineers (ASME), and Association for Computing Machinery (ACM).

This project aimed to create a code of ethics for robotics engineers in a format similar to that of the ACM and IEEE, while addressing the aspects unique to robotics engineering. This code needed to take into account the fact that the robotics industry is rapidly growing in many different directions. Engineers dealing with robotics have only the codes from other disciplines to follow, which may not adequately address the ethical issues that will undoubtedly arise in robotics engineering. In the last several years, the field of roboethics, the ethics of robotics, has emerged, but no comprehensive set of ethical guidelines has yet been created to address robotic engineering.

The target audience of this code is robotics engineers, engineers working with robotics, as well as students and professors studying robotics. While this is the target audience, the code is also able to be understood by the layperson, so that the public can know what the ethical standards for robotics engineers are. As such, the creation of this code took into account the thoughts and views of a wide range of people in the form of surveys and discussions. Research into past work involving professional ethics and past conferences on robot ethics, as well as the current and projected state of robotics was also used in the creation of this code.

A first draft of the code was written in October of 2009, at which point it was presented to the target audiences for critique through discussions. These critiques were then taken into account in revising the code multiple times. Before the final version was completed, the code was sent to various industry professionals for their input. A short paper about the creation of the code was presented at the ACM/IEEE Human Robot Interaction conference in Osaka, Japan in March

2010. The robotics engineering fraternity on campus, Rho Beta Epsilon, was interested in the possibility of adoption, and the code will be hosted on the Illinois Institute of Technology website's list of ethical codes in the professions. Revisions of the code will continue for some time and the group is expected to present at a conference on Roboethics at WPI in April 2010.

Literature Review

Introduction

Ethical codes are found across most educated professions. Professional engineers in many fields agree to these codes from their professional societies. There currently exists no governing body devoted solely to professional robotics engineers, and as such no code of ethics to govern their behavior. Robotics engineering is a rapidly growing field with many unique aspects that will undoubtedly lead to ethical situations not addressed in existing engineering ethical codes. Presently, however, there is a growing concern in this area and the field roboethics is gaining momentum.

General Ethics

Ethics addresses morality, whether that morality is defined by law, belief or religion. However, none of these can be correct by themselves. Emotion can lead us to do things that are ethically wrong (such as stealing out of jealousy), and though many religions hold a high ethical standard it cannot be the only constraint since there are many people who do not practice a religion and yet still understand ethical boundaries. The law cannot be the only standard of ethical behavior for a similar reason: though laws are most often designed to follow the ethics of the people that abide by them, there have been and still are laws that contradict those ethics (such as the pre-Civil War slavery laws). And finally, the accepted behavior of society cannot be defined as ethics. This is because there have been instances in the past where a society has accepted behavior that is considered by others to be unethical, such as Nazi Germany or the practice of slavery.

So, how does one define ethics? Ethical actions respect the rights of others and are best for society. Ethics defines what people ought to do, to best follow these sets of rules. But ethics is also always changing, so the other half to being ethically sound is to constantly examining our personal definition of ethics, and to make sure the things we do or create follow those ethics that we find to be reasonable and based on solid truths. (Velasquez, 1987)

Ethics is a branch of philosophy dealing with what is right and what is wrong. It deals with figuring out how to tell if something is right or wrong and seeks to provide good reasons for belief in a certain position. In doing this it can show that what may seem to be intuitively true is not. (Sanbonmatsu, 2009)

Ethics and morals are often considered to be the same thing, but in practice have substantial differences that are important to recognize when examining codes of ethics. Morals are what one believes to be right or wrong, whereas ethics are morals with reasoning beyond simple belief substantiating them. A code of ethics has been thought through, with reasons for each of its statements, whereas morals can be based largely on emotions or beliefs rather than logic, possibly resulting in unethical decisions. (Weber, 2008)

Looking at the etymology of morality and ethics, morality originated from the Latin word *mos*, meaning manner or custom. Ethics originated from the Greek word *ethos*, meaning character or moral nature. These origins show that from the beginning these words had slightly different connotations. Morality also has multiple definitions, one of which is that it is synonymous with ethics in that it is the study of morals and what is right or wrong in various situations. In other definitions, morality is a description of what a particular person or group believes to be right or wrong. These multiple definitions of morality serve to blur the line between ethics and morality, although ethics has connotations that it was arrived at by a more formal thought process than morality. (Wikipedia, 2009a)

In colloquial use among philosophers, ethics is moral philosophy and morals are societal beliefs. Under this definition, a society's morals may not be ethical, as their morals are merely the belief of the majority. There are, however, philosophers who believe in what is called relativist ethics, that what is right is determined by what the majority believe. (Sanbonmatsu, 2009)

John Cowan argues that ethical questions boil down to "what will make me happy." By reducing ethics to this question, ethics is no longer a barrier to being happy, greatly simplifying decision making and making it easier to behave ethically. This assumes that one realizes that one's happiness depends on the happiness of those around them, encouraging one to take actions that will be beneficial to more than just themselves, and to not take actions that will cause unnecessary grief to others. (Cowan, 2001)

Professional Ethics

Professional ethics help to provide guidance for professionals so that they can serve each other and society as well as possible, without the fear of other professionals undercutting them with less ethical practices. One of the earliest codes of professional ethics was the Hippocratic Oath. This provided rules for doctors to follow so as to not harm their patients. This let patients know what to expect from doctors and made them more inclined to trust their doctors, thereby helping both the profession and themselves. (Wikipedia, 2009c)

The Hippocratic Oath provides very clear guidelines for what a physician can and can't do, and places limitations on both physical actions and intent. It seeks to protect both a patient's life and privacy, while also forbidding things such as abortions. The code opens by swearing to various gods to follow the oath, and the entire code is written from the first person. (North, 2002)

The format and principles behind modern codes of ethics were defined largely in the early 1800's. Prior to this time, codes of ethics were very subjective and the enforcement to them was only an individual's sense of honor. These codes were taken as oaths and were written in the first person, not meant to outline acceptable practices and actions, but instead relied entirely on the individual to determine the correct course of action in any given instance. This meant that a person's perceived character was critical, and there was incentive to defame other professionals, especially if one viewed their practices to be questionable and gave them an edge over one's self.

In order to correct this issue in the medical profession, Thomas Percival published a new code of ethics. Thomas Percival, a physician, was asked to head a committee to write a set of regulations in 1792, following a dispute between surgeons that resulted in patients being turned away during an epidemic. Two years after working on these regulations, Thomas Percival wrote "Medical Jurisprudence or a Code of Ethics and Institutes' Adapted to the Professions of Physic and Surgery". This code actually defined acceptable conduct, taking away the subjectivity of previous codes. It also did not use the first person, further discouraging personal interpretations of the code. This helped to encourage that the code be interpreted more consistently by different individuals, so that the standards were more universally applied. It also provided clauses for defying the instructions of employers if those instructions were not in the best interest of patient's health. (Percival, 1803)

Following the creation of this code, many other organizations followed its lead, recognizing the advantages it held. Modern professional codes can be observed to have these same attributes, outlining what a professional's primary duties are and to whom, as unambiguously as possible. (Baker, 1999)

Examples of such codes include those of the Institute of Electrical and Electronics Engineers (IEEE), American Society for Mechanical Engineers (ASME), and the Association for Computing Machinery (ACM). All three have codes which their members are expected to abide by, and both follow the example that Thomas Percival set in their structure and goals. These particular codes are of interest because the organizations they belong to represent the three major facets of robotics engineering, electrical engineering, mechanical engineering, and computer science.

The IEEE code of ethics code is very concise and provides general guidelines which apply to all engineering and most technical fields. The code is an attempt to hold the members of the IEEE to a high standard of practice and in so doing better the public perception of the field of engineering. By following this code, members ensure that the public will be willing to continue working with members of the IEEE. This code goes into very little depth and, as a result, contains only concepts which most everyone would agree are acceptable. It also includes nothing that would apply only to electrical and electronics engineers, and could be easily applied to any other field of engineering. (IEEE, 2006)

This contrasts with the ACM code of ethics in several ways. The ACM code's core statements are simple and would apply to any professional field, or indeed even outside the professional world, but the explanations of these statements are oriented heavily towards professionals working with software and computers. These general statements are then supplemented by more specific responsibilities of its members, and a section devoted entirely to roles of leadership. A final and brief section discusses compliance with the code, stating that members must uphold each principle and to expect the same from other members. The principles and statements of the code are provided with the intention that how they are interpreted is up to the reader, except where it is provided specifically. The code also says that the supplementary guidelines were intended to have additions or alterations as time goes by, whereas the code itself should be altered far less often, though it is still acceptable. (ACM, 1992)

The ASME code of ethics has three main parts: the fundamental principles, the fundamental canons, and criteria for interpretation of the canons. Each of the sections is progressively more detailed. There are three fundamental principles, which are mostly ideals, such as engineers being responsible for using their knowledge for the betterment of mankind. There are eight fundamental canons, which are more specific, but still deal with the topics presented in the fundamental principles. There are 9 criteria for interpretation of these canons, each with subsets, which give concrete examples of situations engineers might face and instructs engineers on what to do in these situations (ASME, 2007). Most of the criteria consist of things that engineers shouldn't do.

A professional code of ethics needs to take into account a great many factors, with the foremost of these being limiting harm to the many communities that the code needs to protect. Defining harm itself is also difficult, as there are many different types of harm, including physical, emotional, but also societal effects, such as the inattentiveness displayed by people on cell phones or texting. The communities considered also need to have some sort of hierarchy, with the most encompassing having the highest, as harm to it would have the largest effect. (Sanbonmatsu, 2009)

Schomberg argues that modern ethical codes place too much responsibility on the individual, when in reality it is large groups of people that are making decisions, and that any decision an individual does make can have many unintended consequences. The vast number of people with responsibilities in any given engineering project means that an individual may not be aware that one of their decisions will have horrible consequences. (Schomberg, 2007)

Codes of professional ethics, although excellent standards to adhere to, do not have any legal weight. Organizations with codes of professional ethics may impose sanctions for breaching the code of ethics, but the most that the organization can do is expel the offending engineer, unless some law was violated. If an engineer is brought to court for a flaw in the engineer’s work, professional codes of ethics will not be considered, only the relevant laws. Many codes of ethics hold professionals to higher standards than the law would otherwise, making it important to recognize that the engineer may not legally be liable if the engineer breaches the code of ethics as long as all laws are followed. (Rissmiller 2010)

Current State of Robotics Industry

Any discussion of ethics and robotics must involve extensive knowledge of the state of the art. The field of robotics represents an extraordinarily talented and capable group of technologies, and the industry is still moving ahead by leaps and bounds. Robots are already learning, walking and interacting with humans in ways that were previously the stuff of science fiction. There exists a myriad of applications for robots in fields such as pure research applications, well-funded military uses, and even consumer products.

By far the most common type of robot in use today is the industrial robot. Most of the industrial robots in use today are robot arms, but they exist in a variety of configurations and can accomplish many different types of tasks. Employed extensively in manufacturing, they perform welding, painting, assembly, product inspection, and many other tasks (Wikipedia 2009g). Industrial robots can accomplish these tasks with far greater endurance, speed, and precision than any human, while also avoiding needless risk. They can either be programmed to repeat the same set of motions over and over, or they can utilize cameras and machine vision software to track objects and interact with them. Robot arms can be fitted with different end effectors, peripherals on the end of the arm, which are usually highly specialized to suit the task it is set up for. Currently there exists an arm configuration and end effectors to suit virtually any welding, manipulating, or quality control task, as well as smaller arms for use in laboratories.

One of the most well-known humanoid robots is Asimo. Developed by Honda, Asimo is a humanoid robot capable of walking, running, and performing tasks with its hands (Wikipedia, 2009d). It represents the state of the art in walking robots and software. Its software can recognize moving objects, gestures, sounds, and faces. It is capable of walking at 2.7 km/hour and running at 6 km/hour. It can walk around and perform basic tasks such as picking up an object, shaking a person's hand, and pushing a cart, and is also capable of accessing networks and communicating with other Asimo units. Currently Asimo units are mostly used for experimental purposes, but can be rented out to companies for about $166,000 per year.

In addition to humanoid robots which can walk and perform tasks like a human, there is also research into creating androids, or robots that closely resemble humans. Hanson Robotics specializes in robotic heads that resemble human faces to an extremely high degree of accuracy (Reuters 2009). This is made possible partially by a new, highly flexible material for the skin of the robots that requires much less force to manipulate, and thus allows realistic facial expressions to be simulated with less power consumption than ever before. The company also develops artificial intelligence to go along with the robots which allows them to interact with humans through conversation. According to Hanson, each of the robots has a "personality.” One of the most advanced robots the company has built is "Albert-Hubo," a walking robot with a body similar to Asimo and a head that resembles Albert Einstein.

Japanese engineers created a robot in 2007 that was meant to mimic an infant human in both appearance and function (AFP, 2009). The engineers responsible believed that robots and infants have some similar characteristics; both are limited in terms of their initial capabilities, and both must learn from their surroundings. After its first year of learning, the robot known as Child-robot with Biometric Body (CB2) had learned to walk across the room after watching a human teacher. Its current learning task is to observe the facial expressions of its creators and separate them into happy expressions and sad expressions so that it can later recreate them when applicable. CB2's engineers hope to have it speaking in simple sentences at a two year-old level within the next two years. The Machine Perception Laboratory at the University of California has also made a robot that resembles a small child and has similar goals to the CB2 project. Named “Diego-San” the collaboration between the University of California and Japanese company Kokoro Co, it has the ability to stand up and grasp objects and is being used to study how infants learn non-verbal communication (Ackerman 2010).

Not only have robots started to learn, they have also begun to make their own significant scientific discoveries (Ravilious, 2009). ADAM is a robotic scientist capable of understanding a problem, proposing a hypothesis, designing appropriate experiments, and finally carrying those experiments out using attached hardware. ADAM's overseers at Aberystwyth University in Wales, U.K. gave ADAM a crash course in the biology of baker's yeast and the robot set off by proposing and testing 20 hypotheses. ADAM eventually discovered the gene responsible for the creation of enzymes needed for yeast metabolism. The university is also working on a new robot, EVE, designed to assist researchers in finding treatments for tropical diseases.

The military is one of the biggest investors in the robotics industry, and as such military robots are advancing at a rapid rate. The first armed robots were sent to Iraq in mid 2007 (Shachtman, 2007) with the capability to fire on command. The robots, called Special Weapons Observation

Reconnaissance Detection System (SWORDS), are modified versions of ordinance disposal robots, which had been known to occasionally spin out of control without warning. SWORDS has been updated with more safety features, mechanical and electrical safeties on the firearm, and a kill switch that will disable to robot instantly. As of now, SWORDS requires human input in order to fire its weapon, but autonomous fire is not far off.

In fact, other weapons platforms already have the ability to fire autonomously, and the results have not always been positive. In October 2007, an antiaircraft cannon in South Africa that was modified to be fully autonomous killed 9 people and wounded 14 others after a mysterious malfunction during a test (Engelbrecht, 2007). It is unknown exactly what caused the malfunction, but there is suspicion that the company that made the cannon, C2I2, had failed to properly fix known errors and was generally irresponsible in upgrading the original turret.

The US army has also recently had a negative experience with military robots. Recently it decided to recall its SWORDS robots that were deployed in Iraq (Mick, 2008). They don't have the ability to fire without human intervention, but they can perform certain actions autonomously. The recall was issued because one of the robots pointed its weapon at US troops without being given a command to do so. No shots were fired and no one was injured, but the event sparked questions about the reliability of such weapon systems.

Samsung has also developed a robotic sentry gun for use patrolling the Korean Demilitarized Zone (Page, 2007). The gun is outfitted with infrared cameras that allow it to identify and track targets day or night and fire at them with deadly force. It is also outfitted with a speaker and microphone, and can prompt intruders for a password and recognize if the password is valid or not. While designed to be used with a human operator, it is reported to have the ability to fire autonomously.

Boeing has developed an unmanned air combat system that currently has the ability to fly autonomously and carries a payload of smart bombs (Boeing, 2009). If given GPS coordinates of a target, it can fly to the target without human intervention, although currently a human operator must give it permission before it can use a weapon. The plane is still in the development phase, but it has demonstrated its ability to seek out a target and drop a bomb on it, with the only human intervention being the authorization to drop the bomb.

Robots are also used extensively in the medical field. The speed, repeatability, and precision that robots can achieve make them very useful tools for surgery. The DaVinci system is a robotic surgery system that is used to assist surgeons with minimally invasive surgery. It is not autonomous, but rather has a console that a surgeon can sit at to operate the robot, which does all of the surgical work. It improves upon the method of laparoscopy, making it easier and more comfortable for surgeons to perform it (Intuitive Surgical 2008). Surgeries done with the DaVinci system generally have less risk of infection and involve shorter hospital stays than traditional surgery. The Cyberknife is another robotic surgery system. It is a non-invasive surgery system designed to treat tumors using precisely-controlled doses of radiation. Unlike some forms of radio surgery, the Cyberknife does not require any restraints drilled into the patient's skull to minimize movement. Instead, it utilizes sophisticated tracking software that can track the movement of the patient and adjust the path of the radiation treatment in real time (Accuray 2008). Another benefit the Cyberknife has over traditional surgery is that it can operate on complex tumors that may be otherwise considered inoperable.

Along with a growth in sophistication, robots have also become common enough that the average consumer can purchase one. The Roomba, a floor-cleaning robot made by iRobot, was introduced in 2002 and has sold over 2.5 million units to date (Wikipedia, 2009b). It is a wheeled robot about the same size and shape of a Frisbee that can autonomously vacuum floors and return to its charging station without bumping into objects or falling down stairs. Since the Roomba's introduction, the iRobot company has expanded its product line to include robots that can clean pools, wash floors, and clean gutters. While the Roomba isn't the most technically advanced robot today, it represents the state of the art because it is widely available and well-known. As such it is likely one of the few robots that an average person would have had the opportunity to be in contact with, and has a strong influence on the public's perception of what a robot is.

The Study of Roboethics

In 2004, the First International Symposium on Roboethics was held in Sanremo, Italy. (Veruggio, 2004) The term "roboethics" was created by Gianmarco Veruggio, the organizer of this conference. He and many others involved in the field of Robotics felt that the ethical questions raised by developing technologies needed to be collected and discussed in order to prevent a major ethical catastrophe. (Wikipedia, 2009e)

Ronald C. Arkin, of the Mobile Robotics Laboratory at Georgia Institute of Technology, believes that not only is it inevitable that robots will be used by the military to kill, it is also ethical (Arkin 2007) Arkin proposed that due to a robot's natural attentiveness to predetermined rules, they will undoubtedly be able to be more ethical than human soldiers. His thesis is: “Robots can ultimately be more humane than human beings in military situations”. The incident at Abu Ghraib, Iraq and the inhumane treatment of prisoners by the UK military are also brought up as evidence of the inhumanity of man towards man in wartime scenarios. Arkin proposes that it is the duty of robotics engineers to research the ethical questions in robotics and apply them to military robotics in order to prevent further inhumanity. An ethical basis is what makes a military robot into what Arkin calls a “Humane-oid.” This ethical basis for robots could be written using protocols of the Geneva Convention, Rules of Engagement and Code of Conduct.

In a similar vein, some have argued that since humans can build machines that can perform many tasks better than a human, it will eventually be possible to build a robot or AI program that acts even more morally than a human. If true this could lead to humans being replaced by robots in professions that require a high degree of moral decision-making. In fact, Pamela McCorduck argues that people may even prefer robot judges and police, stating, "I'd rather take my chances with an impartial computer" (Wikipedia, 2009f).

In 2007, the South Korean government announced its plans to begin work on a Robot Code of Ethics and has formed a 5-person task force to oversee its completion. The code is not meant to specifically for robot makers, but instead focuses on social issues dealing with human-robot interaction and legal issues of machines that can make their own decisions, referred to as "intelligent service robots" (Lovgren 2007). Parts of the code will also deal future issues that may arise if robots become intelligent enough to demand legal rights, which, according to the British government, could be a possibility in the next 20 to 50 years (BBC 2006). Since 2007, the Korean government has not publicly released the charter nor has it supplied any new information concerning it.

In an attempt to start the discussion of rules governing robotics engineers, Jamais Cascio has proposed five simply stated laws that he believes will help to protect the public, the creator and the creation (Cascio 2009). The first of these laws states that “creation has consequences,” which he explains is a reminder to engineers that robots are not yet fully capable of making high level decisions, “so they can't be blamed for mistakes.” Cascio asserts the second law as, “Politics Matters”, which is simply meant to remind that robots have creators and certain biases, whether political or even cultural, are sure to exist in the programming. According to his third law, the blame for all consequences will rest solely on the creators. The fourth law, “No Such Thing as a Happy Slave,” brings about the question of robot rights. If society starts blaming robots for their mistakes instead of their creators, then it might be time to consider rights for robots. The final law is titled “Don't Kick the Robot” and requires that robots be able to express danger or risk to itself in order to elicit an empathy response from the human user. These laws are meant to be taken as a general guideline, and Cascio admits that a formal code governing roboethics will be necessary in the future.

An article concerning robot ethics was recently featured in the 2010 February edition of Popular Mechanics. In the article “The Uncertain Future for Social Robots,” a new class of robots, called social robots, is introduced. Social robots differ from other types or robots in that rather than being designed to accomplish a specific task more efficiently than humans, they are designed specifically to interact with people through speech and motion. The article claims that one of the most advanced social robots is called Nexi and is built by researchers at MIT. Nexi can recognize faces and carry on basic conversations with people and is capable of emulating a wide variety of facial expressions and movement. However, some have described Nexi as “creepy,” which the article attributes to a phenomenon called the uncanny valley. The uncanny valley is a phenomenon in which highly realistic androids can seem scary or disturbing to some people, allegedly because the androids are so humanlike that they trigger conflicting signals as to whether or not they are human. The article also notes that many people enjoyed interacting with Nexi and even started to empathize with it. These two responses highlight an important issue in the field of social robotics. If robots interact with humans and are made to look like humans, how they interact with humans and what applications they are used for are very important. The article warns that the makers of social robots could exploit the emotional connections that people form with them. The article also poses the question of whether or not it is wrong to use social robots to take care of children or the elderly. (Segal, 2010)

Professionals in the field have expressed the need for ethical standards in the robotics industry, both to govern the actions of robots and to outline proper behavior of robotics engineers. In his book, *Wired for War*, P. W. Singer writes that the ethics of the robot industry is “hindered by the absence of professional codes or traditions that robotics scientists might look to when trying to figure out the ethical solution to a difficult science problem. (Singer 2009) While many professionals agree that there is a need for such code, some have expressed fears that a code of ethics for robotics engineers could be used to hold legally responsible for damages caused by robots they have built, despite this not being the intent of such a code. However, professional ethical codes are generally too vague to be use as evidence in a court case. (Appendix D)

With the field of robotics being so new and in such rapid development, robots are expanding their capabilities faster than humans can fully realize the implications of them. They can already perform many tasks as well as an average human could, as well as perform certain tasks faster or with a higher degree of precision than any human. With each new capability robots gain, a new ethical question is asked. How are these questions to be answered? Talks on the issue of roboethics have already begun, but the industry needs a formal code that can be referred to whenever a large development is made.

Methodology

The first step in drafting the code of ethics was compiling a list of about 100 situations which a robotics engineer might encounter. This list of situations served as a means of identifying important themes and ethical questions of the nature of the robotics industry. A list of communities was created and defined to guide the creation of the code. These communities are those that a robotics engineer must be ultimately aiming to help and improve. Each group member individually penned a handful of draft code points that covered the important themes in the list of situations and would be of benefit to the listed communities. These points were then discussed within the group and assembled into the first draft of the code of ethics. In order to fully understand all points considered in the drafting of the code, each principle was assigned to a pair of group members for further analysis to promote deeper understanding.

In order to ensure broad acceptance of the final product, many points of view needed to be taken into consideration. Moderate sized groups were formed using members of the WPI undergraduates. Discussion points covered issues about the use of robots in the military, the responsibilities of robotics engineers and concerns about the future of the robotics field. The group also distributed a survey concerning similar topics at the Robotics Innovation Competition and Conference at WPI. The survey was distributed to all in attendance at the conference, including students and professionals in the robotics field.

Initial discussions within the group and with advisors showed that the list of communities developed for drafting the code would serve well as an overarching introduction to the code. It was decided that this would serve as the main text for the code's preamble. The conclusion section was added when the group understood that the field of robotics engineering will inevitably grow in unforeseen and maybe unpredictable directions. It was decided that the code would need to admit its own limitations and encourage further ethical discussion and development within the robotics community.

Based on the results of further discussions and research, the code was further refined weekly. Each part and principle of the code was scrutinized to ensure and understand its clarity, necessity, and social implications.

After the first draft of the code was completed, it was presented to as many interested parties as possible with the intent of receiving as much informed feedback from the robotics community as possible. The feedback was gathered and discussed within the group and used to further refine the code. The group presented its code to several groups within the local community including the faculty of the Robotics Engineering program at WPI and Rho Beta Epsilon, the robotics engineering honors fraternity at WPI. With the help of the head of the robotics program, the code was sent to the leaders of many regional robotics businesses including iRobot and Bluefin Technologies. The code was also sent to the ethics committees of the IEEE, ACM and ASME as well as the ethics center at the Illinois Institute of Technology. The ethics center of IIT agreed to host the code in its collection of professional codes of ethics.

To help get more feedback and to present the code to a large professional audience, a short paper was submitted and accepted to the Human and Robot Interaction to be held in March 2010 in Osaka, Japan. This paper includes a short description of the group's methodology and the code in its entirety. Advisor Charles Rich presented the paper and collected feedback for the group to discuss upon his return.

The code was also presented to both Rho Beta Epsilon and the faculty of the robotics engineering program at WPI to receive feedback on the code of ethics as well as to see if either group would be willing to adopt the code. Both groups agreed with the intentions of the first point, which implies that a robotics engineer should be considering all the possible consequences of actions, but the groups felt that the point was worded in such a way that it did not convey the intent properly and could be interpreted as far too restricting. Having received similar feedback at both presentations, the team then discussed and revised the point to make it more concise. Rho Beta Epsilon has expressed an interest in adopting a later version of the code.

Analysis

Need for a code of ethics for robotics engineers

There are many professional codes of ethics for many different professions from many different professional organizations. These codes of ethics for the most part provide very similar guidelines for the organization's members to follow. The organizations most closely related to robotics engineering, the IEEE, ASME, and ACM, each have codes with many elements which are directly applicable to robotics engineering. Robotics engineering, however, will also present new and unique challenges, largely due to the potential autonomy of robots and the level of interaction with humans that robots will undoubtedly achieve. These issues are addressed in the periphery in these other codes of ethics, but a code useful for robotics engineers should address these situations more directly. Ideally, this code of ethics should also include explanations more specific to the situations which a robotics engineer is likely to encounter, similar to how the ACM code of ethics provides guidance specific to computer scientists. This helps to clarify the code for the intended audience and makes the intent behind the code more clear.

Specific examples of ethical situations unique to robotics engineers arise primarily from the autonomous decision making that characteristically defines robots. The most controversial situation that a robotics engineer may be confronted with is the design of completely autonomous robots with lethal capabilities. This situation asks the engineer to make the ethical decision of whether or not to make a robot that will decide for itself if and when to take human life,

A less controversial example, although still equally unique to robotics engineering, is the production and design of autonomous motor vehicles. Although autonomous cars have been in development for many years, they have not yet been placed in the hands of the public. This is because any autonomous entity will inevitably be expected to make a mistake, whether in decision-making or purely mechanically. Such a mistake could be fatal, and as such the public wants to know where the responsibility for a robot's decision will lie. A robotics engineer needs to decide when a product is safe and ready to be used by the public and what training or qualification the individual users must have.

Another example unique to robotics engineers is that of privacy issues and household robots with vision systems or microphones. Such robots could store private information without the knowledge or consent of the owner, and this information could be accessed by those with bad intentions. A robotics engineer must make sure that privacy rights are respected and protected.

Discussion on military robots

Worldwide, defense research is undoubtedly the largest sponsor of the modern robotics industry. Robotic systems have already been designed to use lethal force and the capability of autonomous target identification and tracking is already realized. The question facing robotics engineers now is whether or not it is ethical to continue further in making fully autonomous robotic soldiers a reality.

There are several main arguments against giving robots the ability to use lethal force against a human. Some believe that all forms of warfare are unethical and must be avoided at all costs, and that when robots are sent as replacements for real soldiers, people will become less sensitive to the destruction inherent in war. When leaders can send robots to fight battles they will no longer need to find diplomatic solutions to international disputes. Even if the battles of future wars are settled between two armies of robotic soldiers, there will undoubtedly still be civilian casualties and destruction. However, if a leader is only losing some metal and silicone instead of the lives of citizens, the leader might overlook these repercussions instead of finding a peaceful solution. Not only would the battlefield of this future be based upon the robotic prowess of a nation, it would also rely on its ability to economically supply its robotic soldiers. Lethal robots could lead to more frequent and “easier” wars of economic and robotic strength.

However, given the assumptions that war will not stop in the foreseeable future, and that war can sometimes be ethical, one can argue that lethal robots can be the most ethical solution in some cases. These assumptions are very controversial, but the first can be witnessed in history and the second can be argued easily from a consequentialist point of view. Under some situations, war can be declared such that a populous is saved from severe oppression or certain death, and it is in these situations that war can be viewed as an ethical means to a justifiable end.

Under these assumptions, one may argue that the use of lethal robots in war could be an ethical practice. When it has been decided that the use of robots is not only necessary, but the quickest and most efficient way to end a war, then it is an ethical use of lethal robots. Leaders have the responsibility to endanger as few lives as possible, so by ending a conflict as quickly and efficiently as possible, a leader is ensuring the safety of as many of his people as possible.

The use of robots in warfare has changed and will undoubtedly continue to change the strategy behind modern military strategy. Robots can be used to more safely and easily locate and identify hostile targets by sending them in as the front line, so as to draw fire from the enemy before placing human soldiers into danger. With more robotic soldiers, there will be less necessity for human soldiers and therefore fewer resources being used by soldiers. These saved resources can be used to further robotics research for both lethal and nonlethal robots.

Focus Group discussions

What are your opinions of robots in the military?

Most responses to the use of non-lethal robots in the military were entirely positive. Those in attendance were comfortable with the use of completely autonomous non-lethal robots by the military, such as surveillance robots.

The reactions to robots with lethal capabilities, however, were much more skeptical and led to very interesting discussion. Many initial responses were completely against fully-autonomous lethal robots due to either a general uneasiness about giving weapons to robots or because of the repercussions that such autonomous killing machines could have upon the use of warfare. The latter argument asserts that when the human cost of war is less, then wars will be more frequent.

The conclusion that some members of the focus groups came to was that lethal robots could find an acceptable, even desirable, place in the military under several circumstances. Some believed that if a robot could be proved to be more discriminate and accurate in determining hostile targets and if they could cause minimal collateral damage, then and only then would autonomous lethal robots be an acceptable replacement for human soldiers. When asked if the use of these robots would be ethical, it was this group that argued that it would be. Their argument was that if robots can neutralize a threat to human life without posing a threat to civilians and non-hostile targets, then it would be the ethically responsible choice to deploy autonomous lethal robots.

The other members of the group did not believe that autonomous lethal robots would be ethical. They worried that these robots could be acquired by those with little concern for human life and could use them too quickly and effortlessly kill innocent people. Another concern is the very real possibility of robot malfunctions because a machine with lethal power may be very difficult to stop and could cause a lot of damage if it were to malfunction.

To what extent should an engineer be held responsible for the actions of his creations?

At first, most replied that an engineer should not be held responsible for his creations at all because the use of the robot relies entirely on the end user. The exceptions to this conclusion are if the engineer does not specify the precise limitations of the use and capabilities of the robot or if the robot fails to perform to the explicit specifications given to the end user. Some, however, did argue that engineers should always feel responsible for the actions of their creations. As one of these dissenters argued, “if you make a robot that is meant to kill people, then how is it not your fault that those people have died?”

To what extent should an engineer be responsible for the misuse of his creations?

It was fairly unanimous in all groups that the misuse of a creation is not the responsibility of robotics engineers. It cannot be expected of engineers to be able to anticipate and fix every possible misuse because it would cost too much for every precaution to be designed and implemented. If this were to be attempted, there is little chance that a group of engineers could be able to identify and prevent every possible misuse. One argued, however, that if you give a robot lethal power, then you have a lot more responsibility as an engineer than an engineer designing a vacuuming robot. It was generally accepted that misuse should at least be considered by robotics engineers.

What is your biggest concern about the future of the robotics industry?

The most common response to this question was concern over the displacement of human jobs. When asked if engineers have an ethical responsibility to find a solution to this most responded that the responsibility should fall on the shoulders of policy makers. Others were concerned that there may be people that will block the progress of robotics due to misunderstanding and misinformation. Another concern was the ultimate impact on human ideas and skills when robots begin to do more and more skilled tasks.

Code of Ethics for Robotics Engineers

Preamble

As an ethical robotics engineer, I understand that I have the responsibility to keep in mind at all times the well-being of the following communities:

Global – the good of people and known environmental concerns

National – the good of the people and government of my nation and its allies

Local – the good of the people and environment of affected communities

Robotics Engineers – the reputation of the profession and colleagues

Customers and End-Users – the expectations of the customer and end-user

Employers – the financial and reputational well-being of the company

Principles

To this end and to the best of my ability I will...

1- Act in such a manner that I would be willing to accept responsibility for the actions and uses of anything in which I have a part in creating.

It is the responsibility of a robotics engineer to consider the possible unethical uses of the engineer's creations to the extent that it is practical and to limit the possibilities of unethical use. An ethical robotics engineer cannot prevent all potential hazards and undesired uses of the engineer's creations, but should do as much as possible to minimize them. This may include adding safety features, making others aware of a danger, or refusing dangerous projects altogether. A robotics engineer must also consider the consequences of a creation's interaction with its environment. Concerns about potential hazards or unethical behaviors of a creation must be disclosed, whether or not the robotics engineer is directly involved. If unethical use of a creation becomes apparent after it is released, a robotics engineer should do all that is feasible to fix it.

2- Consider and respect peoples' physical well-being and rights.

A robotics engineer must preserve human well-being while also respecting human rights. The United Nations' Universal Declaration of Human Rights (http://www.un.org/en/documents/udhr/index.shtml) outlines the most fundamental of these rights. Privacy rights are especially of concern to a robotics engineer. A robotics engineer should ensure that private information is kept secure and only used appropriately. There are circumstances when honoring privacy rights or other rights conflict with preserving the well-being of an individual or group. In these cases, a robotics engineer must decide the ethical course of action, making sure the least harm is done.

3- Not knowingly misinform, and if misinformation is spread do my best to correct it.

A robotics engineer must always remain trustworthy by not misinforming customers, employers, colleagues or the public in any way. A robotics engineer must disclose when the engineer feels unqualified to safely or fully complete a required task. When others spread misinformation, a robotics engineer must do as much as possible to correct the misinformation.

4- Respect and follow local, national and international laws wherever applicable.

A robotics engineer must follow the laws of the applicable communities. This includes where the robotics engineer is working and the communities targeted by the outcome of the engineer's work. The intellectual rights of others should be maintained at all times and assistance received from others should always be properly credited.

5- Recognize and disclose any conflicts of interest.

A robotics engineer must disclose the existence of any conflicts of interest to employers. It is up to the robotics engineer to decide how to react to any such conflict, either by attempting to ignore personal feelings or by avoiding the source of conflict.

An employer must be aware of conflicts and that these conflicts of interest may affect the robotics engineer's decisions. Bribery inherently creates conflicts of interest and is unethical.

6- Accept and offer constructive criticism.

A robotics engineer should always strive to produce the best work possible and to help others do the same. For this reason, a robotics engineer must both give and accept constructive criticism. This allows for robotics engineers to help improve each other's work, benefiting each other and those affected by the robotics engineer's work. A robotics engineer who refuses to consider criticism risks making avoidable mistakes.

7- Help and assist colleagues in their professional development and in following this code.

This code of ethics is available as a guideline for all robotics engineers as a means of uniting them with a common basis for ethical behavior. In following this code, a robotics engineer promotes the positive perception of the field by customers and the general public. In helping colleagues develop professionally and ethically, a robotics engineer makes sure that the field of robotics will continue to grow.

Conclusion

This code was written to address the current state of robotics engineering and cannot be expected to account for all possible future developments in such a rapidly developing field. It will be necessary to review and revise this code as situations not anticipated by this code need to be addressed.

Reasoning Behind the Code

This code of ethics seeks to address the issues that a robotics engineer is likely to encounter, with the primary difference between this code and other professional codes of ethics being the emphasis placed on the robotics engineer's responsibilities. The preamble clearly states the primary concern the robotics engineer should have, to protect the well being of those affected by the robotics engineer's actions. The remaining points are more specific considerations that the robotics engineer must keep in mind while working towards this end.

1- Act in such a manner that I would be willing to accept responsibility for the actions and uses of anything in which I have a part in creating.

It is the responsibility of a robotics engineer to consider the possible unethical uses of the engineer's creations to the extent that it is practical and to limit the possibilities of unethical use. An ethical robotics engineer cannot prevent all potential hazards and undesired uses of the engineer's creations, but should do as much as possible to minimize them. This may include adding safety features, making others aware of a danger, or refusing dangerous projects altogether. A robotics engineer must also consider the consequences of a creation's interaction with its environment. Concerns about potential hazards or unethical behaviors of a creation must be disclosed, whether or not the robotics engineer is directly involved. If unethical use of a creation becomes apparent after it is released, a robotics engineer should do all that is feasible to fix it.

This principle is arguably the most applicable and necessary to ethical robotics engineers because of the limitless nature of their field in terms of capabilities and applications of their creations. This principle recognizes that final responsibility may not rest upon the single engineer, but it should always be on the mind of engineers that they may be held responsible and they should act accordingly.

Robotics engineers especially need to be wary of the potential misuse of their creations. Due to the common uses of robots, they are in a particularly sensitive position of misuse. A robot that is designed to interact with humans could harm someone easily, and robots used in sensitive surgical procedures needs to be protected against hacking or other misuse to prevent the potential injury of a patient. Outside of personal injury, robots are also often used in manufacturing, where a slight change in the calibration or programming of a robot could cost a manufacturer millions of dollars within a few hours of incorrect operation. Because of the nature of interaction with expensive, dangerous, or otherwise human subjects, the robots are a dangerous factor in everyday life when not properly safeguarded from unethical use or security breaches.

This principle attempts to address the modern issue of responsibility when it comes to the actions of a robot, such as an autonomous car that may run a red light. Engineers designing such a car may look at this principle and decide to not continue with the project due to the potential hazards, but they could also decide to continue with the project as long as all of the limitations of the final product are passed along to the users of the product. For example, the engineers may recommend that an occupant of the car will always be aware of the car's actions and be prepared to take control if necessary.

Some have argued that this principle places too much responsibility on an engineer working on a small part of a project without knowledge of the larger picture. One example given was an engineer working on a gearbox for a robot that was designed to kill water buffalo. This engineer may not have any information as to the overall goals of the project. But, even without this information, the engineer can still be in following with this code, as the engineer can still make sure that the gearbox will function as designed and not harm the communities of the preamble. Since the engineer is not told of the final uses of the greater creation, the engineer cannot be responsible for the actions of the final product. The engineers and managers responsible for overall robot design, target acquisition software and integration, however, would be ethically responsible to ensure the product is ethical. These employees might question their employers about the ethicality of the creation, help them find another, more humane solution or terminate their connections with the project.

An ethical group of robotics engineers should always be looking out for one another and making sure that the products being produced are safe and ethically sound. Not only is this good business practice, it also ensures that the field of robotics engineering remains a respected and trusted field. The public's perception of robots and robotics engineering will determine the viability of the field, and thus the ability for robotics engineers to be employed and relevant. If the public knows that robotics engineers are acting in such a manner to be willing to accept responsibility, then the field will be trusted and given the opportunity to grow and profit.

2- Consider and respect peoples' physical well-being and rights.

A robotics engineer must preserve human well-being while also respecting human rights. The United Nations' Universal Declaration of Human Rights (http://www.un.org/en/documents/udhr/index.shtml) outlines the most fundamental of these rights. The intellectual rights of others should be maintained at all times. Assistance received from others should always be properly credited. Privacy rights are especially of concern to a robotics engineer. A robotics engineer should ensure that private information is kept secure and only used appropriately. There are circumstances when honoring privacy rights or other rights conflict with preserving the well-being of an individual or group. In these cases, a robotics engineer must decide the ethical course of action, making sure the least harm is done.

This point was designed to directly call out one of the main goals of ethical codes, to minimize harm. This point directly addresses this and tells the robotics engineer to take into account the physical well being and rights of the people and communities affected by the engineer's creations. Care also had to be taken to ensure that this principle was not overly limiting. If this point had mandated that robotics engineers create only robots that have no possibility of harming people or infringing on their rights, then it would be impossible for a robotics engineer to create anything. Instead this point only requires that the robotics engineer consider and respect these. This leaves the robotics engineer free to create thing which have the possibility of violating people's rights, but makes sure that the robotics engineer believes that it is as safe as possible in this respect and that the possible benefits outweigh the risks.

This point also does not preclude the creation of armed military robots. It is up to the robotics engineer to determine if the armed robot in question would do more good than harm, and if the hands that it is put in would be responsible enough to regulate its use. The robotics engineer is also able to decide not to ever create an armed robot if it is believed that any such robot would do more to violate people's rights than protect them.

This point also makes sure to point out that people's rights, not just their physical well being, must be respected. Most people take for granted that they should protect the physical well being of people, and in many instances in engineering, that is the only major area that must be considered. With current technology privacy rights are also of major concern, especially in computer science. This will carry over to robotics and become even more of a concern as robots have the potential to unobtrusively observe and record many aspects of their environment and the people around them. Further human rights issues may also arise, as robots become more advanced and human robot interaction becomes more common. For this reason it is important for the robotics engineer to take these into consideration.

3- Not knowingly misinform, and if misinformation is spread do my best to correct it.

A robotics engineer must always remain trustworthy by not misinforming customers, employers, colleagues or the public in any way. A robotics engineer must disclose when the engineer feels unqualified to safely or fully complete a required task. When others spread misinformation, a robotics engineer must do as much as possible to correct the misinformation.

Most of the other codes examined had principles concerning engineers conducting their business with honesty, as it is an issue that is not unique to robotics engineers. Any engineer that builds a product must be aware that misinformation about that product could be very dangerous. Customers and engineers working on a product must be aware of the product's abilities, specifications, and limitations. Misunderstanding of this information by a customer or engineer could lead to hazardous operation of the product, and put people in harm's way. Full disclosure is also important, as omission of critical details could be just as dangerous as the spread of false information. Thus, if an engineer knows something about a product that would be necessary to safely operate it, it is the duty of the engineer to make sure that the information is provided and represented accurately.

While this situation is not unique to robotics engineers, it is especially important to robotics engineers, and is therefore stated explicitly in the code. Many robots are designed for military and law enforcement applications, and are sometimes equipped with lethal force. In these cases, it is a matter or safety that the people operating the robots be aware of all of the robot's abilities. Also, if a robot is experimental, it is extremely important that all test participants be aware of any known issues the system currently has, and all precautions that should be taken to ensure that the test is conducted safely. As robots increasingly become consumer products, other ethical issues develop.

Unlike many other fields of engineering, the public developed many misconceptions about robotics engineering before it had gotten started. Early science fiction and modern Hollywood films greatly exaggerate the capabilities of modern robotics, and yet, are the main source of information for the public about robotics. It is for this reason that robotics engineers should be wary of the public's perception of robotics. As misinformation is spread to the public, it is very likely that the public will become less willing to accept robots into daily life. It is for these reasons that it is also in the best interest of engineers to educate the public about robots and the robotics industry.

The wording of this principle was chosen very carefully. It reads "if misinformation is spread, do my best to correct it" to make it clear that it is the engineer's responsibility not only to correct misinformation that he or she accidentally spreads, but also to correct misinformation that is spread by others, either accidentally or deliberately. This is not intended to burden the engineer with responsibility for other people's actions, but to remind engineers that they have a duty to keep others informed, especially when they are aware that information is being spread which they know is false or inaccurate. If everyone takes the responsibility of correcting misinformation as soon as they find out about it, the spread of mistakes or deliberate falsifications will be greatly inhibited. This should lead to greater safety in the workplace and in the lives of consumers.

4- Respect and follow local, national and international laws wherever applicable.

Robotics engineers must follow the laws of the applicable communities. This includes where the robotics engineer is working and the communities targeted by the outcome of their work.

The values and interests of individual communities can differ greatly, even within one country. These communities develop their own sets of practices and rules to help guide their community and anything that enters it. For robotics engineers this means that any project they are involved in can and often will be subject to an appraisal using these local laws, and so they should make considerable effort to understand and follow them.

Laws often change drastically when crossing an international boarder. It is the responsibility of any international traveler to be familiar with the laws of the region in which they are going. This is especially important for robotics engineers, because they often won't have to consider only their own impact, but the impact of their work. Understanding and complying with the laws of an individual nation is absolutely essential to the success of projects that affect the people there.

International laws are intended for all human beings to abide by and should always be considered by robotics engineers to be absolute. Ignoring these laws would not only tarnish an engineer's individual reputation, but the reputation of the trade, and should not be tolerated under anything but the harshest circumstances.

5- Recognize and disclose any conflicts of interest.

Robotics engineers must disclose the existence of any conflicts of interest to their employers. It is up to the robotics engineer to decide how to react to any such conflict, either by attempting to ignore personal feelings or by avoiding the source of conflict. An employer must be aware of conflicts and that these conflicts of interest may affect the robotics engineer's decisions. Bribery inherently creates conflicts of interest and is unethical.

Robotics engineers base many of their decisions on scientific methods. They are expected to be unbiased and to make decisions based on facts and evidence. Any personal opinions or emotions that could affect the decision-making process of an engineer should be avoided. However, engineers are human, and it is impossible to completely remove all sources of bias. Every engineer will inevitably be faced with a conflict of interest at some point, and merely having a conflict of interest is not unethical as long as it is dealt with correctly. The correct way to deal with a conflict of interest will vary depending on the situation and the magnitude of the conflict. In some cases, the engineer may be able to merely ignore the source of the bias. In other cases, the decision may need to be made by another, less biased party. In most cases, the employer should be made aware of the conflict of interest, so the engineer's decisions can be put in the proper context. This principle was intended to remind engineers to deal with conflicts of interest while still being flexible enough to leave the decision of how to deal with it up to the engineer.

This principle also explicitly prohibits bribery because bribery creates an unfair conflict of interest by definition. Bribery will only make the engineer's decision biased and less accurate. Both giving and receiving bribes should be avoided in all cases.

6- Accept and offer constructive criticism.

Robotics engineers should always be looking to produce the best work possible and to help others do the same. For this reason, robotics engineers must both give and accept constructive criticism. This allows for robotics engineers to help improve each other's work, benefiting each other and those affected by the robotics engineer's work. A robotics engineer who refuses to consider criticism risks making avoidable mistakes.

From the hierarchy of communities in the beginning of the code, it is clear that an engineer's work should always be for the greater good and put the needs of others above selfish personal gain. As such, it is helpful both to an engineer's company and to the profession as a whole that engineers be able to learn from each other and be continuously improving their work. This means giving colleagues constructive criticism on how to improve their work, and accepting any criticism given. This relates to principle 7 in that engineers should help each other develop professionally. In a fast-moving discipline such as robotics, it is imperative that engineers are always improving themselves and staying aware of the state of the art. One of the best and easiest ways to accomplish this goal is for colleagues to learn from each other.

This principle is also a matter of safety as it ties in with principle 3. As stated in principle 3, engineers are obligated to report any safety issues that they are aware of, even if they are not involved in the project. If one engineer tells another engineer about a known safety issue, it could be considered professional or constructive criticism. When this happens, it is the duty of the engineer to accept this criticism and take the necessary corrective measures. If the engineer ignores this criticism, whether due to pride or laziness, it could have disastrous effects for customers, the public, and the company. It is for this reason that all engineers should accept constructive criticism from their peers and should be able to provide constructive criticism without the fear of retribution or negative consequences.

7- Help and assist colleagues in their professional development and in following this code.

This code of ethics is available as a guideline for all robotics engineers as a means of uniting them with a common basis for ethical behavior. In following this code, a robotics engineer promotes the positive perception of the field by customers and the general public. In helping colleagues develop professionally and ethically, a robotics engineer makes sure that the field of robotics will continue to grow.

The goal behind an engineering code of ethics is to unify engineers with a basis for moral and ethical decision-making. When some engineers decide to go against this common code, they make it more difficult for other engineers to continue following the code. By encouraging others to follow the code, engineers will be able to stand on a level footing and give the profession a positive reputation.

Engineers should always be looking to improve skills and techniques so as to better themselves and their creations. They should also help other engineers do the same, so that their company and profession will strengthen and better itself.

IEEE Comparison

The Code of Ethics for Robotics Engineers is intended to stand alone as an ethical guide for robotics engineers. As an example, the IEEE code of ethics follows with point by point comparisons with the Code of Ethics for Robotics Engineers.

We, the members of the IEEE, in recognition of the importance of our technologies in affecting the quality of life throughout the world, and in accepting a personal obligation to our profession, its members and the communities we serve, do hereby commit ourselves to the highest ethical and professional conduct and agree:

1. to accept responsibility in making decisions consistent with the safety, health and welfare of the public, and to disclose promptly factors that might endanger the public or the environment;

This point calls for the engineer to take responsibility in decisions and intents of the overall project. The code for robotics engineers asks robotics engineers to act in a manner that the engineer would be comfortable taking personal responsibility for the actions and uses, and not just the intent of the creation. This point of the IEEE code is more closely related to the preamble and the principle code that reminds engineers to recognize peoples' rights and well-being.

2. to avoid real or perceived conflicts of interest whenever possible, and to disclose them to affected parties when they do exist;

The robotics engineering code is worded more simply and asks the engineer to recognize and disclose. If the robotics engineer and the employer believe that the quality of work will remain unchanged in the face of the conflict, then it is not necessary to avoid the conflict of interest.

3. to be honest and realistic in stating claims or estimates based on available data;

This point is covered in the preamble of the robotics code in doing good to customers and in not misinforming them. The explanation of principle three begins by reminding the engineer to be trustworthy.

4. to reject bribery in all its forms;

This point is not explicitly stated in a principle because it was thought to be too specific. Bribery, by definition, creates conflicts of interest and is illegal in most communities, both of which are covered under specific principles.

5. to improve the understanding of technology, its appropriate application, and potential consequences;

Through discussion it was found that improving the understanding of technology is not intrinsically an ethical behavior. Certainly, breaking this point by not improving the public's understanding is not unethical, as it does not harm any community. Misinforming the public, however, is very easily seen as unethical and counterproductive to the field of robotics engineering. Educating the public is indeed beneficial to the public and to the field of robotics, which is why it is suggested to the robotics engineer in the explaining paragraph of point 3.

6. to maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations;

In being willing to take responsibility for the engineer's creations, the engineer is certifying that all work done can be trusted by the customer and the public. Technical competence and qualification are both necessary in honestly being willing to take responsibility.

7. to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others;

Constructive criticism is encouraged in principle 6, and the explaining paragraph describes why a responsible engineer should take this criticism into consideration. The paragraph of principle 2 explains that others have the right to be properly credited for input.

8. to treat fairly all persons regardless of such factors as race, religion, gender, disability, age, or national origin;

Discrimination goes against the most basic of human rights and is also illegal in most communities. An engineer should need no reminders of this.

9. to avoid injuring others, their property, reputation, or employment by false or malicious action;

This point is covered in not doing harm to the communities in the preamble and in recognizing the rights and well-being of others. False or malicious action against any person or group is the basis of any unethical act and should therefore not need a specific principle to acknowledge this.

10. to assist colleagues and co-workers in their professional development and to support them in following this code of ethics.

This point is also made in the robotics code of ethics.

Future Work

As mentioned in the conclusion of the code of ethics, the code we have created will need to be revised as new capabilities of the robotics field are closer to realization. There are several ways in which this code can be improved in the future,

The first of these improvements is to create a supplementary code of ethics or set of ethical guidelines with the intent of governing robotic behavior. The code in its current state covers the way robotics engineers interact with their environment, whereas the proposed supplement would directly cover a robot's interaction with its environment. The robotics community may one day agree that it is unethical for a robot to impersonate a human. This could be added to the code as part of a supplementary set of principles.

It may also be desirable to strengthen the code of ethics. Many certainly make the case that any form of killing is unethical, and this belief could lead some to wish the code to ban robotics engineers from creating robots with lethal capabilities. If an organization, or the field of robotics engineers, feels this way, it will be necessary to make this stronger distinction in the second principle. The code was written in such a way to encourage broad acceptance, but it is also easily strengthened if this is the ethical stance of an adopting body.

The code will need to be changed, and it is the hope of the group that the code will grow with and provide a direction for the field of robotics engineering.

Future revisions to this code may be made by any organization which adopts it, or organizations may adopt pieces of it into their own codes of ethics. These revisions may be to address new issues developing in robotics engineering, or changes in wording to better align the code with the mission of the adopting organization.

Conclusions

After reviewing many codes written for engineering societies, they were found to be lacking in certain areas that needed to be addressed by a single code of ethics written specifically for robotics engineers. A code designed to cover the unique issues of robotics engineering as well as general engineering ethics was written, revised and distributed to industry professionals. The final version of the code is being considered for adoption by the robotics honors fraternity on campus, Rho Beta Epsilon, and is hosted on the internet by the Illinois Institute of Technology center for ethics. Work on this project will continue as the code is distributed to both robotics engineers and the general public. The official code will be maintained and discussed on an online forum at rbethics.lefora.com.

Works Cited

(AFP, 2009) AFP. Japan child robot mimics infant learning [Internet]. Google News; Apr 4, 2009 Available from: http://www.google.com/hostednews/afp/article/ALeqM5j1F1VEHktMpXSaXrLUgr4coIDfPg [Accessed 2009 Sep 22]

(Ravilious, 2009) Kate Ravilious. First Robot Scientist Makes Gene Discovery [Internet], National Geographic News; April 2, 2009 Available from: http://news.nationalgeographic.com/news/2009/04/090402-robot-scientists.html [Accessed 2009 Sep 22]

(Shachtman, 2007a) Noah Shachtman. First Armed Robots on Patrol in Iraq (Updated) [Internet]. Wired; August 2, 2007 3:56 PM Available from: http://www.wired.com/dangerroom/2007/08/httpwwwnational/ [Accessed 2009 Sep 22]

(Engelbrecht, 2007) Leon Engelbrecht. Did software kill soldiers? [Internet]. ITWeb; October 16, 2007 Available from: http://www.itweb.co.za/sections/business/2007/0710161034.asp?S=IT%20in%20Defence&A=DFN&O=FPTOP [Accessed 2009 Sep 22]

(Page, 2007) Lewis Page. South Korea to field gun-cam robots on DMZ [Internet]. The Register; March 17, 2007 12:34 GMT Available from: http://www.theregister.co.uk/2007/03/14/south_korean_gun_bots/ [Accessed 2009 Sep 22]

(Boeing, 2009) Boeing. X-45 Joint Unmanned Combat Air System [Internet]. Available from: http://www.boeing.com/history/boeing/x45_jucas.html [Accessed 2009 Sep 22]

(Wikipedia, 2009a) Wikipedia contributors. Morality [Internet]. Wikipedia, The Free Encyclopedia; 2009 Sep 23, 16:34 UTC. Available from:

http://en.wikipedia.org/w/index.php?title=Morality&oldid=315736430. [Accessed 2009 Sep 23]

(Wikipedia, 2009b) Wikipedia contributors. Roomba [Internet]. Wikipedia, The Free Encyclopedia; 2009 Sep 18, 23:59 UTC. Available from: http://en.wikipedia.org/w/index.php?title=Roomba&oldid=314820892. [Accessed 2009 Sep 22]

(Velasquez, 1987) Manuel Velasquez, Claire Andre, Thomas Shanks, S.J., and Michael J Meyer. What is Ethics?. *Issues in Ethics* IIE V1 N1; Fall 1987 Available From: http://www.scu.edu/ethics/practicing/decision/whatisethics.html

(Cowan, 2001) John Cowan. Happiness, The Goal of Ethics [Internet]. NewWork Opinion; 2001. Available from: http://www.newwork.com/Pages/Contributors/Cowan/Happiness.html [Accessed 2009 Sep 22]

(Wikipedia, 2009c) Wikipedia contributors. Hippocratic oath [Internet]. Wikipedia, The Free Encyclopedia; 2007 Dec 1, 16:08 UTC. Available from: http://en.wikipedia.org/w/index.php?title=Hippocratic_oath&oldid=175072394. [Accessed 2009 Sep 22]

(North, 2002) Thomas North, The Hippocratic Oath [Internet]. National Library of Medicine. 2002. Available from: http://www.nlm.nih.gov/hmd/greek/greek_oath.html

(Baker, 1999) Robert Baker. Codes of Ethics: Some History. Perspectives on the Profession; Fall 1999. Available from: http://ethics.iit.edu/perspective/v19n1%20perspective.pdf

(Percival, 1803) Thomas Percival. Medical Ethics. 1803. Available from http://books.google.com/books?id=tVsUAAAAQAAJ&dq=thomas+percival+medical+code&source=gbs_navlinks_s

(IEEE, 2006) Members of IEEE. IEEE Code of Ethics; February 2006. Available from: http://www.ieee.org/portal/pages/iportals/aboutus/ethics/code.html

(ASME, 2007) Members of ASME. The ASME Criteria for Interpretation of the Canons; November 16, 2007. Available from*:* *files.**asme**.org/**asme**org/NewsPublicPolicy/Ethics/10938.doc*

(ACM, 1992) ACM Council. ACM Code of Ethics and Professional Conduct; 1992 Oct 16. Available from: http://www.acm.org/about/code-of-ethics

(Schomberg, 2007) European Commission. From the Ethics of Technology towards an Ethics of Knowledge Policy & Knowledge Assessment; January 2007. Paper presented at the 2007 IRCA Full Day Workshop on Roboethics, Rome, April 14, 2007. Available from: http://www.roboethics.org/icra2007/contributions/VON%20SCHOMBERG%20Ethics%20of%20Technology%20Knowledge%20Policy.pdf

(Mick, 2008) Jason Mick. Iraqi War Robots Recalled Following Alarming Behavior. Inside Tech; April 11, 2008. Available from: http://insidetech.monster.com/news/articles/1743-iraqi-war-robots-recalled-following-alarming-behavior
[Accessed 2009 Sep 23]

(Wikipedia, 2009d) Wikipedia contributors. ASIMO [Internet]. Wikipedia, The Free Encyclopedia; 2009 Sep 20, 13:08 UTC. Available from: http://en.wikipedia.org/w/index.php?title=ASIMO&oldid=315088184.
[Accessed 2009 Sep 23]

(Veruggio, 2004) Proceedings of First International Symposium on Roboethics. Villa Nobel, Sanremo Italy. 2004 January 30-31, http://www.roboethics.org/sanremo2004/
[Accessed 2009 Oct 14]

(Wikipedia, 2009e) Wikipedia contributors. Roboethics [Internet]. Wikipedia, The Free Encyclopedia; 2009 Sep 24, 12:06 UTC. Available from: http://en.wikipedia.org/w/index.php?title=Roboethics&oldid=295758937
[Accessed 2009 Sep 24]

(Arkin 2007) *Lethality and Autonomous Systems: An Ethical Stance.* [Presentation slides]. IEEE International Conference on Robotics and Automation; April 2007. Paper presented at the

2007 IRCA Full Day Workshop on Roboethics, Rome, April 14, 2007. Retrieved from: http://www.roboethics.org/icra2007/contributions/slides/Arkin_icra07_ppt.pdf

(Wikipedia, 2009f) Wikipedia contributors. Ethics of artificial intelligence [Internet]. Wikipedia, The Free Encyclopedia; 2009 Aug 27, 17:13 UTC. Available from: http://en.wikipedia.org/w/index.php?title=Ethics_of_artificial_intelligence

[Accessed 2009 Sep 30]

(Lovgren 2007) Stefan Lovgren. Robot Code of Ethics to Prevent Android Abuse, Protect Humans [Internet] National Geographic News, March 16, 2007. Available from: http://news.nationalgeographic.com/news/2007/03/070316-robot-ethics.html [Accessed 2009 Sep 30]

(BBC 2006) Robots could demand legal rights [Internet] BBC News, Thursday, 21 December 2006, 13:54 GMT Available from http://news.bbc.co.uk/2/hi/technology/6200005.stm [Accessed 2009 Sep 30]

(Cascio 2009) Jamais Cascio. Machine Ethics [Internet] Fast Company, April 27, 2009. Available from: http://www.fastcompany.com/blog/jamais-cascio/open-future/machine-ethics [Accessed 2009 Sep 30]

(Reuters 2009) Reuters. Einstein Robot Head Dazzles Tech Conference [Internet] Fox News, Tuesday, February 10, 2009. Available from http://www.foxnews.com/story/0,2933,490104,00.html [Accessed 2009 Oct 7]

(Sanbonmatsu, 2009) John Sanbonmotsu. Personal Interview. Monday, October 5, 2009

(Intuitive Surgical 2008) Intuitive Surgical Incorporated. Da Vinci Product Site [Internet] Available from: http://www.davincisurgery.com/davinci-surgery/davinci-surgical-system/features.html

[Accessed 2009 Oct 13]

(Accuray 2008) Accuray Incorporated. Cyberknife Patient Brochure [Internet] Available from: http://www.cyberknife.com/uploadedFiles/CyberKnife_Overview/Patient%20Brochure.pdf

[Accessed 2009 Oct 13]

(Wikipedia 2009g) Wikipedia contributors. Industrial Robot [Internet]. Wikipedia, The Free Encyclopedia; 2009 Oct 7, 11:04 UTC. Available from: http://en.wikipedia.org/w/index.php?title=Industrial_robot

[Accessed 2009 Oct 14]

(Segal 2010) Gregg Segal. The Uncertain Future for Social Robots. [Internet] Popular Mechanics February 2010 Available from: http://www.popularmechanics.com/science/robotics/4343892.html?page=1

[Accessed 2010 Feb 9]

(Ackerman 2010) Evan Ackerman. Robot Babies Are Always a Mistake. [Internet] Botjunkie January 12, 2010 Available from: http://www.botjunkie.com/2010/01/12/robot-babies-are-always-a-mistake/

[Accessed 2010 Feb10]

(Singer 2009) P. W. Singer. *Wired for War* P 422 The Penguin Press. 2009

(Rissmiller 2010) Kent Rissmiller. Personal Email. Thursday, February 11, 2010.

Appendix A: IEEE Code of Ethics

We, the members of the IEEE, in recognition of the importance of our technologies in affecting the quality of life throughout the world, and in accepting a personal obligation to our profession, its members and the communities we serve, do hereby commit ourselves to the highest ethical and professional conduct and agree:

1. to accept responsibility in making decisions consistent with the safety, health and welfare of the public, and to disclose promptly factors that might endanger the public or the environment;

2. to avoid real or perceived conflicts of interest whenever possible, and to disclose them to affected parties when they do exist;

3. to be honest and realistic in stating claims or estimates based on available data;

4. to reject bribery in all its forms;

5. to improve the understanding of technology, its appropriate application, and potential consequences;

6. to maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations;

7. to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others;

8. to treat fairly all persons regardless of such factors as race, religion, gender, disability, age, or national origin;

9. to avoid injuring others, their property, reputation, or employment by false or malicious action;

10. to assist colleagues and co-workers in their professional development and to support them in following this code of ethics.

Appendix B: ASME Code of Ethics

4/23/09
SOCIETY POLICY
ETHICS
ASME requires ethical practice by each of its members and has adopted the following Code of Ethics of Engineers as referenced in the ASME Constitution, Article C2.1.1.
CODE OF ETHICS OF ENGINEERS
The Fundamental Principles
Engineers uphold and advance the integrity, honor and dignity of the engineering profession by:
I. using their knowledge and skill for the enhancement of human welfare;
II. being honest and impartial, and serving with fidelity their clients (including their employers) and the public; and
III. striving to increase the competence and prestige of the engineering profession.
The Fundamental Canons
1. Engineers shall hold paramount the safety, health and welfare of the public in the performance of their professional duties.
2. Engineers shall perform services only in the areas of their competence; they shall build their professional reputation on the merit of their services and shall not compete unfairly with others.
3. Engineers shall continue their professional development throughout their careers and shall provide opportunities for the professional and ethical development of those engineers under their supervision.
4. Engineers shall act in professional matters for each employer or client as faithful agents or trustees, and shall avoid conflicts of interest or the appearance of conflicts of interest.
5. Engineers shall respect the proprietary information and intellectual property rights of others, including charitable organizations and professional societies in the engineering field.
6. Engineers shall associate only with reputable persons or organizations.
2 P-15.7
4/23/09
7. Engineers shall issue public statements only in an objective and truthful manner and shall avoid any conduct which brings discredit upon the profession.
8. Engineers shall consider environmental impact and sustainable development in the performance of their professional duties.
9. Engineers shall not seek ethical sanction against another engineer unless there is good reason to do so under the relevant codes, policies and procedures governing that engineer’s ethical conduct.
10. Engineers who are members of the Society shall endeavor to abide by the Constitution, By-Laws and Policies of the Society, and they shall disclose knowledge of any matter involving another member’s alleged violation of this Code of Ethics or the Society’s Conflicts of Interest Policy in a prompt, complete and truthful manner to the chair of the Committee on Ethical Standards and Review.
The Committee on Ethical Standards and Review maintains an archive of interpretations to the ASME Code of Ethics (P-15.7). These interpretations shall serve as guidance to the user

of the ASME Code of Ethics and are available on the Committee's website or upon request.
Responsibility: Centers Board of Directors/Center for Professional Career and
Professional Advancement/Committee on Ethical Standards and Review
Reassigned from Centers Board of Directors/Center for Professional
Development, Practice and Ethics/Committee on Ethical Standards and
Review 4/23/09
Reassigned from Council and Member Affairs/Board on Professional
Practice & Ethics 6/1/05
Adopted: March 7, 1976
Revised: December 9, 1976
December 7, 1979
November 19, 1982
June 15, 1984
(editorial changes 7/84)
June 16, 1988
September 12, 1991
September 11, 1994
June 10, 1998
September 21, 2002
September 13, 2003
(editorial changes 6/1/05)
November 5, 2006
(editorial changes to the responsible unit 4/09)

Appendix C: ACM Code of Ethics

Preamble

Commitment to ethical professional conduct is expected of every member (voting members, associate members, and student members) of the Association for Computing Machinery (ACM).

This Code, consisting of 24 imperatives formulated as statements of personal responsibility, identifies the elements of such a commitment. It contains many, but not all, issues professionals are likely to face. Section 1 outlines fundamental ethical considerations, while Section 2 addresses additional, more specific considerations of professional conduct. Statements in Section 3 pertain more specifically to individuals who have a leadership role, whether in the workplace or in a volunteer capacity such as with organizations like ACM. Principles involving compliance with this Code are given in Section 4.

The Code shall be supplemented by a set of Guidelines, which provide explanation to assist members in dealing with the various issues contained in the Code. It is expected that the Guidelines will be changed more frequently than the Code.

The Code and its supplemented Guidelines are intended to serve as a basis for ethical decision making in the conduct of professional work. Secondarily, they may serve as a basis for judging the merit of a formal complaint pertaining to violation of professional ethical standards.

It should be noted that although computing is not mentioned in the imperatives of Section 1, the Code is concerned with how these fundamental imperatives apply to one's conduct as a computing professional. These imperatives are expressed in a general form to emphasize that ethical principles which apply to computer ethics are derived from more general ethical principles.

It is understood that some words and phrases in a code of ethics are subject to varying interpretations, and that any ethical principle may conflict with other ethical principles in specific situations. Questions related to ethical conflicts can best be answered by thoughtful consideration of fundamental principles, rather than reliance on detailed regulations.

Contents & Guidelines

1. GENERAL MORAL IMPERATIVES.

As an ACM member I will ....

1.1 Contribute to society and human well-being.

This principle concerning the quality of life of all people affirms an obligation to protect fundamental human rights and to respect the diversity of all cultures. An essential aim of computing professionals is to minimize negative consequences of computing systems, including threats to health and safety. When designing or implementing systems, computing professionals must attempt to ensure that the products of their efforts will be used in socially responsible ways, will meet social needs, and will avoid harmful effects to health and welfare.

In addition to a safe social environment, human well-being includes a safe natural environment. Therefore, computing professionals who design and develop systems must be alert to, and make others aware of, any potential damage to the local or global environment.

1.2 Avoid harm to others.

"Harm" means injury or negative consequences, such as undesirable loss of information, loss of property, property damage, or unwanted environmental impacts. This principle prohibits use of computing technology in ways that result in harm to any of the following: users, the general public, employees, employers. Harmful actions include intentional destruction or modification of files and programs leading to serious loss of resources or unnecessary expenditure of human resources such as the time and effort required to purge systems of "computer viruses."

Well-intended actions, including those that accomplish assigned duties, may lead to harm unexpectedly. In such an event the responsible person or persons are obligated to undo or mitigate the negative consequences as much as possible. One way to avoid unintentional harm is to carefully consider potential impacts on all those affected by decisions made during design and implementation.

To minimize the possibility of indirectly harming others, computing professionals must minimize malfunctions by following generally accepted standards for system design and testing. Furthermore, it is often necessary to assess the social consequences of systems to project the likelihood of any serious harm to others. If system features are misrepresented to users, coworkers, or supervisors, the individual computing professional is responsible for any resulting injury.

In the work environment the computing professional has the additional obligation to report any signs of system dangers that might result in serious personal or social damage. If one's superiors do not act to curtail or mitigate such dangers, it may be necessary to "blow the whistle" to help correct the problem or reduce the risk. However, capricious or misguided reporting of violations can, itself, be harmful. Before reporting violations, all relevant aspects of the incident must be thoroughly assessed. In particular, the assessment of risk and responsibility must be credible. It is suggested that advice be sought from other computing professionals. See principle 2.5 regarding thorough evaluations.

1.3 Be honest and trustworthy.

Honesty is an essential component of trust. Without trust an organization cannot function effectively. The honest computing professional will not make deliberately false or deceptive claims about a system or system design, but will instead provide full disclosure of all pertinent system limitations and problems.

A computer professional has a duty to be honest about his or her own qualifications, and about any circumstances that might lead to conflicts of interest.

Membership in volunteer organizations such as ACM may at times place individuals in situations where their statements or actions could be interpreted as carrying the "weight" of a larger group of professionals. An ACM member will exercise care to not misrepresent ACM or positions and policies of ACM or any ACM units.

1.4 Be fair and take action not to discriminate.

The values of equality, tolerance, respect for others, and the principles of equal justice govern this imperative. Discrimination on the basis of race, sex, religion, age, disability, national origin, or other such factors is an explicit violation of ACM policy and will not be tolerated.

Inequities between different groups of people may result from the use or misuse of information and technology. In a fair society, all individuals would have equal opportunity to participate in, or benefit from, the use of computer resources regardless of race, sex, religion, age, disability, national origin or other such similar factors. However, these ideals do not justify unauthorized use of computer resources nor do they provide an adequate basis for violation of any other ethical imperatives of this code.

1.5 Honor property rights including copyrights and patent.

Violation of copyrights, patents, trade secrets and the terms of license agreements is prohibited by law in most circumstances. Even when software is not so protected, such violations are contrary to professional behavior. Copies of software should be made only with proper authorization. Unauthorized duplication of materials must not be condoned.

1.6 Give proper credit for intellectual property.

Computing professionals are obligated to protect the integrity of intellectual property. Specifically, one must not take credit for other's ideas or work, even in cases where the work has not been explicitly protected by copyright, patent, etc.

1.7 Respect the privacy of others.

Computing and communication technology enables the collection and exchange of personal information on a scale unprecedented in the history of civilization. Thus there is increased potential for violating the privacy of individuals and groups. It is the responsibility of professionals to maintain the privacy and integrity of data describing individuals. This includes taking precautions to ensure the accuracy of data, as well as protecting it from unauthorized access or accidental disclosure to inappropriate individuals. Furthermore, procedures must be established to allow individuals to review their records and correct inaccuracies.

This imperative implies that only the necessary amount of personal information be collected in a system, that retention and disposal periods for that information be clearly defined and enforced, and that personal information gathered for a specific purpose not be used for other purposes without consent of the individual(s). These principles apply to electronic communications, including electronic mail, and prohibit procedures that capture or monitor electronic user data, including messages, without the permission of users or bona fide authorization related to system operation and maintenance. User data observed during the normal duties of system operation and maintenance must be treated with strictest confidentiality, except in cases where it is evidence for the violation of law, organizational regulations, or this Code. In these cases, the nature or contents of that information must be disclosed only to proper authorities.

1.8 Honor confidentiality.

The principle of honesty extends to issues of confidentiality of information whenever one has made an explicit promise to honor confidentiality or, implicitly, when private information not directly related to the performance of one's duties becomes available. The ethical concern is to respect all obligations of confidentiality to employers, clients, and users unless discharged from such obligations by requirements of the law or other principles of this Code.

2. MORE SPECIFIC PROFESSIONAL RESPONSIBILITIES.

As an ACM computing professional I will ....

2.1 Strive to achieve the highest quality, effectiveness and dignity in both the process and products of professional work.

Excellence is perhaps the most important obligation of a professional. The computing professional must strive to achieve quality and to be cognizant of the serious negative consequences that may result from poor quality in a system.

2.2 Acquire and maintain professional competence.

Excellence depends on individuals who take responsibility for acquiring and maintaining professional competence. A professional must participate in setting standards for appropriate levels of competence, and strive to achieve those standards. Upgrading technical knowledge and competence can be achieved in several ways: doing independent study; attending seminars, conferences, or courses; and being involved in professional organizations.

2.3 Know and respect existing laws pertaining to professional work.

ACM members must obey existing local, state, province, national, and international laws unless there is a compelling ethical basis not to do so. Policies and procedures of the organizations in which one participates must also be obeyed. But compliance must be balanced with the recognition that sometimes existing laws and rules may be immoral or inappropriate and, therefore, must be challenged. Violation of a law or regulation may be ethical when that law or rule has inadequate moral basis or when it conflicts with another law judged to be more important. If one decides to violate a law or rule because it is viewed as unethical, or for any other reason, one must fully accept responsibility for one's actions and for the consequences.

2.4 Accept and provide appropriate professional review.

Quality professional work, especially in the computing profession, depends on professional reviewing and critiquing. Whenever appropriate, individual members should seek and utilize peer review as well as provide critical review of the work of others.

2.5 Give comprehensive and thorough evaluations of computer systems and their impacts, including analysis of possible risks.

Computer professionals must strive to be perceptive, thorough, and objective when evaluating, recommending, and presenting system descriptions and alternatives. Computer professionals are in a position of special trust, and therefore have a special responsibility to provide objective, credible evaluations to employers, clients, users, and the public. When providing evaluations the professional must also identify any relevant conflicts of interest, as stated in imperative 1.3.

As noted in the discussion of principle 1.2 on avoiding harm, any signs of danger from systems must be reported to those who have opportunity and/or responsibility to resolve them. See the guidelines for imperative 1.2 for more details concerning harm, including the reporting of professional violations.

2.6 Honor contracts, agreements, and assigned responsibilities.

Honoring one's commitments is a matter of integrity and honesty. For the computer professional this includes ensuring that system elements perform as intended. Also, when one contracts for work with another party, one has an obligation to keep that party properly informed about progress toward completing that work.

A computing professional has a responsibility to request a change in any assignment that he or she feels cannot be completed as defined. Only after serious consideration and with full disclosure of risks and concerns to the employer or client, should one accept the assignment. The major underlying principle here is the obligation to accept personal accountability for professional work. On some occasions other ethical principles may take greater priority.

A judgment that a specific assignment should not be performed may not be accepted. Having clearly identified one's concerns and reasons for that judgment, but failing to procure a change in that assignment, one may yet be obligated, by contract or by law, to proceed as directed. The computing professional's ethical judgment should be the final guide in deciding whether or not to proceed. Regardless of the decision, one must accept the responsibility for the consequences.

However, performing assignments "against one's own judgment" does not relieve the professional of responsibility for any negative consequences.

2.7 Improve public understanding of computing and its consequences.

Computing professionals have a responsibility to share technical knowledge with the public by encouraging understanding of computing, including the impacts of computer systems and their limitations. This imperative implies an obligation to counter any false views related to computing.

2.8 Access computing and communication resources only when authorized to do so.

Theft or destruction of tangible and electronic property is prohibited by imperative 1.2 - "Avoid harm to others." Trespassing and unauthorized use of a computer or communication system is addressed by this imperative. Trespassing includes accessing communication networks and computer systems, or accounts and/or files associated with those systems, without explicit authorization to do so. Individuals and organizations have the right to restrict access to their systems so long as they do not violate the discrimination principle (see 1.4). No one should enter or use another's computer system, software, or data files without permission. One must always have appropriate approval before using system resources, including communication ports, file space, other system peripherals, and computer time.

3. ORGANIZATIONAL LEADERSHIP IMPERATIVES.

As an ACM member and an organizational leader, I will ....

BACKGROUND NOTE:This section draws extensively from the draft IFIP Code of Ethics,especially its sections on organizational ethics and international concerns. The ethical obligations of organizations tend to be neglected in most codes of professional conduct, perhaps because these codes are written from the perspective of the individual member. This dilemma is addressed by stating these imperatives from the perspective of the organizational leader. In this context"leader" is viewed as any organizational member who has leadership or educational responsibilities. These imperatives generally may apply to organizations as well as their leaders. In this context"organizations" are corporations, government agencies,and other "employers," as well as volunteer professional organizations.

3.1 Articulate social responsibilities of members of an organizational unit and encourage full acceptance of those responsibilities.

Because organizations of all kinds have impacts on the public, they must accept responsibilities to society. Organizational procedures and attitudes oriented toward quality and the welfare of society will reduce harm to members of the public, thereby serving public interest and fulfilling social responsibility. Therefore, organizational leaders must encourage full participation in meeting social responsibilities as well as quality performance.

3.2 Manage personnel and resources to design and build information systems that enhance the quality of working life.

Organizational leaders are responsible for ensuring that computer systems enhance, not degrade, the quality of working life. When implementing a computer system, organizations must consider the personal and professional development, physical safety, and human dignity of all workers. Appropriate human-computer ergonomic standards should be considered in system design and in the workplace.

3.3 Acknowledge and support proper and authorized uses of an organization's computing and communication resources.

Because computer systems can become tools to harm as well as to benefit an organization, the leadership has the responsibility to clearly define appropriate and inappropriate uses of organizational computing resources. While the number and scope of such rules should be minimal, they should be fully enforced when established.

3.4 Ensure that users and those who will be affected by a system have their needs clearly articulated during the assessment and design of requirements; later the system must be validated to meet requirements.

Current system users, potential users and other persons whose lives may be affected by a system must have their needs assessed and incorporated in the statement of requirements. System validation should ensure compliance with those requirements.

3.5 Articulate and support policies that protect the dignity of users and others affected by a computing system.

Designing or implementing systems that deliberately or inadvertently demean individuals or groups is ethically unacceptable. Computer professionals who are in decision making positions should verify that systems are designed and implemented to protect personal privacy and enhance personal dignity.

3.6 Create opportunities for members of the organization to learn the principles and limitations of computer systems.

This complements the imperative on public understanding (2.7). Educational opportunities are essential to facilitate optimal participation of all organizational members. Opportunities must be available to all members to help them improve their knowledge and skills in computing, including courses that familiarize them with the consequences and limitations of particular types of systems.In particular, professionals must be made aware of the dangers of building systems around oversimplified models, the improbability of anticipating and designing for every possible operating condition, and other issues related to the complexity of this profession.

4. COMPLIANCE WITH THE CODE.

As an ACM member I will ....

4.1 Uphold and promote the principles of this Code.

The future of the computing profession depends on both technical and ethical excellence. Not only is it important for ACM computing professionals to adhere to the principles expressed in this Code, each member should encourage and support adherence by other members.

4.2 Treat violations of this code as inconsistent with membership in the ACM.

Adherence of professionals to a code of ethics is largely a voluntary matter. However, if a member does not follow this code by engaging in gross misconduct, membership in ACM may be terminated.

This Code and the supplemental Guidelines were developed by the Task Force for the Revision of the ACM Code of Ethics and Professional Conduct: Ronald E. Anderson, Chair, Gerald Engel, Donald Gotterbarn, Grace C. Hertlein, Alex Hoffman, Bruce Jawer, Deborah G. Johnson, Doris K. Lidtke, Joyce Currie Little, Dianne Martin, Donn B. Parker, Judith A. Perrolle, and Richard S. Rosenberg. The Task Force was organized by ACM/SIGCAS and funding was provided by the ACM SIG Discretionary Fund. This Code and the supplemental Guidelines were adopted by the ACM Council on October 16, 1992.

Appendix D: Ethical Questions to Consider When Writing a Code

"Whose fault is it?"

1. A person purchases an assistant-type robot that is used for basic household tasks but is many times stronger than any human. Is this a fault of the designer, seeing as how it could make consumers uncomfortable?
2. Is it an engineer's responsibility to ensure that a robot cannot be used for nefarious purposes, or does the owner/ user take full responsibility?
3. A robot is designed to be safe if used in the proper setting, but the end-user uses it elsewhere, to what degree is the engineer responsible for making sure the robot is safe?
4. Given that a robot has limited perception of its environment, how much leeway can it be given in its treatment of people?
5. Is it a robotics engineer's responsibility to make sure that the robot can never possibly infringe on a person's rights, adding enough sensors and processing to do this?
6. A large number of people work on a genocide robot, who is responsible for it and who should have realized that it was wrong and put a stop to it?
7. Robotic car breaks a traffic law and gets pulled over, who is at fault?
8. Robotic car kills somebody by accident, who is responsible?
9. Military robot malfunctions mistakes civilian for enemy and kills, who is at fault?
10. To what degree is this person(s) responsible?
11. Someone antagonizes robot but poses no threat to humans, to what degree can a robot defend itself?
12. A human has a servant robot with cameras and internet access that is hacked and turned into a spy device, who is at fault and to what degree?
13. Robot is hacked and induced into harming itself, is this ok?
14. Robot is hacked and induced into harming itself, is this ok?
15. If a surgical robot kills a patient due to an unknown bug, who is at fault?
16. ...due to a known but unpublished bug, who is at fault?
17. ...due to a known and published bug, who is at fault?
18. ...due to human error, who is at fault?
19. If a consumer robot has a bug that is considered a present danger to human life, whose responsibility should it be to capture/fix the robot?
20. Robot misidentifies a hostile, asks a human to verify given only the limited misinformation, and pulls trigger, who is responsible?
21. Is it okay for a robot to intervene if it witnesses one human hurting another?

“Should we do this?”

22. Would it be ethical to design a robot that looked almost exactly like a specific person, for the purpose of impersonating him, either in real life or over a video chat?

23. Is it ethical to use an industrial robot for a job that a human could do safely, even if human workers are in plentiful supply?

24. Is it ethical to “employ” robots in other, more skilled professions as they become more adept to handle them?

25. Is it ok to create an industrial robot to take jobs away from people who need them?
26. Is it ok to create an industrial robot to take dangerous jobs away from people who need them? (mining, steel production)

27. Is it ethical to create a robot which gives someone an unprecedented and unfair advantage in some environment? (A robot which buys and sells stock faster than a human can)
28. If it does not harm anyone else?
29. If it at the expense of anyone else?
30. Would this just be a fair capitalistic practice?
31. In replacing a lost arm with a robotic arm, would it be ethical to replace it with an arm with additional functionality?
32. Does a robotics engineer need to consider the potential societal consequences of designing a particular robot? (laziness, inattentiveness as with texting)
33. If robots are given rights according to their sentience, can an engineer design a robot to be underneath this cutoff, essentially limiting its rights for his own profit?
34. Could a robotic police officer have the authority to command people to do things?

35. Is it ethical to use nanobots in medical applications where they are injected into a patient’s body?
36. Is it ethical to use nanobots in environmental applications, such as cleaning up an oil spill, where they are released in large numbers into an ecosystem?
37. Is it ethical to replace emergency personnel with robots in situations where the last thing a person sees might be a robot rather than a human?
38. Is it ethical to replace nurses, daycare workers and other professionals who display empathy and compassion in their work with robots that are not capable of emulating empathy?
39. Is it ethical to replace nurses, daycare workers and other professionals who display empathy and compassion in their work with robots that ARE capable of emulating empathy?
40. If artificial limbs were made that not only replaced a limb, but functioned better than any human limb could, would people that had these limbs be allowed to compete in sporting events.

41. Could people that did not lose their limbs partake is this sort of limb-enhancement?

42. A robotics engineer is not familiar with something he is asked to design, should he design this anyways, even though it may not work properly?

43. A robotics engineer does not receive payment for a delivered robot, is it ok to deactivate it remotely until payment is received?

"What if the unplanned happens?"

44. If a flaw in the programming of a surgical robot is found, how dangerous should the flaw be before all surgical robots of the same models be shut down until the patch is applied?

45. If a consumer robot has a bug that is considered a present danger to human life, should the maker of the robot be allowed to repossess the robot, at least temporarily, and fix it or examine it?
46. Should law enforcement agencies be allowed to repossess the robot also?
47. Should it be a rule that all robots be designed with a "kill switch" or failsafe either in hardware or software?
48. If a failsafe were required on every robot, who should have access to it?
49. If a failsafe were required on every robot, what would it be (ie. Spoken word, button on the robot, wireless signal, remote control, etc)
50. What protocols should be placed on self-replicating nanobots to ensure that there is never an instance of uncontrolled replication?
51. Should nanobots be programmed with an "effective life," after which time they deactivate, to prevent uncontrolled replication?

"Taking Risks"

52. Should a surgeon who owns a surgical robot with a known bug be allowed to take the risk in cases where a patient critically needs surgery and the risk is minor on comparison?

53. In studies of human robot interaction, especially ones involving military equipment, what level of confidence must an engineer have in a robot before it is tested in an environment with humans, where the humans could possibly be harmed?

"Privacy Issues"

54. If a robot is in an application that exposes it to personal information, what safeguards should be required to protect said data from hacking/tampering?

55. If an assistant robot is in the home of someone who is suspected of a crime, should law enforcement agencies be allowed to access information stored in the robot, as well as access live audio and video from the robot to aid them in an investigation?

56. Would it be ethical do design an easy way for police to gain access to a robot for said purposes?

57. When an engineer is servicing a consumer or field-test robot, and the robot has personal data stored in its memory, is the engineer allowed to access such data if it would help him accomplish his job?
58. Is he allowed to access such data if it would not help him accomplish his job?
59. Is he allowed to install software on a robot which would alter the behavior of the robot without the knowledge or consent of the robot owner?
60. Should consumer robots be able to receive software updates automatically if those updates could alter the behavior of the robot?
61. Should a robot be allowed to record audio and video data of a person without his knowledge or consent?
62. Should a robot be allowed to record audio and video data of a person if it witnesses that person committing a crime?
63. Should a robot used by a law enforcement agency be allowed to enter a person's home if the law enforcement agency does not have a warrant and the owner did not provide consent?
64. Should investigators be allowed to search through the memory of a robot while conducting an investigation of a crime?

"Robots that look like people/are they people?"

65. Would it be ethical to build and sell robots that were meant to mimic specific people or celebrities in appearance and personality?
66. Should a robot be allowed to pose as a human in law enforcement situations such as a sting operation?
67. If a robot is asked to identify itself, would it be ethical to design a robot that was instructed to give false credentials to certain people?
68. What are the ethical issues of a robot being mistaken for a person?
69. Does the engineer have a responsibility to inform the person that the robot is a robot?
70. What are the ethics and legality of a robot recording a conversation if the other person were not aware? (Wiretapping laws?)
71. Can a robot be a witness to a crime that it did not commit or is not affected by?
72. Is it ok for a robot to intervene if it witnesses a human harming another human?
73. Can a robot serve jury duty?
74. Can a robot be a judge?
75. If robots are given rights according to thier level of sentience, is it okay to build under a certain level of intelligence? Basically, your taking thier rights by designing them below their maximum potential.
76. In the above case, would it be ethical to use software or hardware to limit the functionality or level of intelligence a robot has?
77. Can a robot be a pet, and deserve the same rights as pets? (ASPCA for robots? ASPCR?)
78. Can a robot be a witness of a crime they did not commit or were not affected by?
79. Can a robot sue someone, or accuse them of wrongdoing against them?
80. Should android robots be forced to have some sort of identifying mark on them so that they cannot be mistaken for a human?

"Military robots"

81. For a military robot, what criteria could it use to determine whether to kill a person?
82. Should robots be given the authority to decide when to use lethal force?
83. Which requirements should be met first?
84. How much ordinance should a robot be given?
85. Where do we draw the line on robots relative to destructive potential? Nukes: obviously not anytime soon. Guns: already happening. Tactical explosives:? Wrecking balls:?
86. Can robots be allowed to make life-death decisions on their own? I.E pull the trigger or administer lethal injections
87. Should robots that carry weapons be allowed to conceal them, or should they be required to always make it known if they have a weapon or not?
88. If robots are forced to somehow identify whether or not they have a weapon, would strength far greater than any human qualify as such a weapon?

"When does the consumer take precedence?"

89. An android robot is malfunctioning and flailing its limbs about wildly. There are humans around but the robot does not pose an immediate threat. It could potentially become a bigger problem and the owner of the robot is not around to remotely shut it off. Do bystanders have the right to damage the robot in order to keep them safe?

90. I f a consumer robot is designed to be many times stronger or faster than a human, what kinds of warnings must be provided to the end user of such a robot?

91. Should the end user of the robot be allowed to "turn down" the strength or speed of a robot to make him more comfortable with the robot.

92. Should the end user of the robot be allowed to "turn down" the intelligence of a robot to make him more comfortable with the robot.

93. In evaluating the cost vs gain of implementing a safety feature, is it ethical to place a value on human life? Is there any other way to reach a conclusion?
94. Large, fast-moving robot is safe, but makes humans uncomfortable, to what degree is it necessary to take human comfort into consideration?
95. Given a budget, can an engineer intentionally leave out possible safety features?
96. When do we consider comfort over necessity? A large robot that moves quickly to be efficient, but if it made an error (which is highly unlikely), it would hurt bystanders. Is it okay for them to just "deal"?

97. If a consumer wants to override safety protocols on a robot, and understands the risks associated with it, and the robot primarily comes into contact only with him, should he be allowed to do so?

98. If a consumer wants to override the safety protocols on a robot, but the robot comes into contact with a large number of people and possibly the general public, should he be allowed to do so?

Appendix E: RICC Survey

Roboethics Survey

This survey is for professors, students, professional engineers, and anyone else with an interest in robotics engineering. This survey is meant to help ascertain the view regarding professional ethics of those involved with the developing field of robotics engineering. This information will be taken into consideration when writing a code of ethics for robotics engineers, similar to the codes of ethics of the IEEE, ASME, and ACM.

If you have any questions or are interested in learning more about this project, feel free to e-mail us at rbethics@wpi.edu

Do you own a robot (either personally or your organization)? If so what type of robot is it? (select all that apply)

a) Industrial
b) Research
c) Medical
d) Toy
e) Home Appliance (Roomba ...)
f) Other : _____________

Do you believe that robots should be armed for use in the military?

a) Strongly agree
b) Agree
c) Indifferent
d) Disagree
e) Strongly disagree

Do you believe that robots should be used by the military for tasks such as surveillance and disarming explosives?

a) Strongly agree
b) Agree
c) Indifferent
d) Disagree
e) Strongly disagree

Do you believe that there should be a code of ethics specifically designed to provide guidance to robotics engineers?

a) Strongly agree
b) Agree
c) Indifferent
d) Disagree
e) Strongly disagree

How comfortable would you be with undergoing surgery done by or assisted by a surgical robot?

a) Very
b) Somewhat
c) Indifferent
d) Mildly uncomfortable
e) Very uncomfortable

Do you believe that an engineer is entirely responsible for the actions and uses of a robot which he creates?

a) Strongly agree
b) Agree
c) Indifferent
d) Disagree
e) Strongly disagree

Any further comments or suggestions:

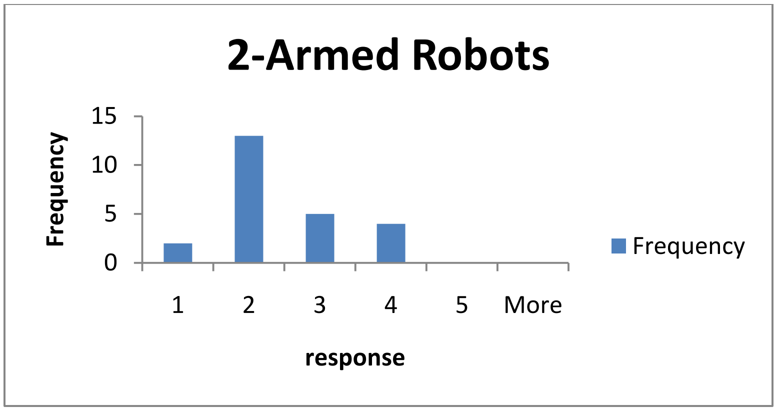
Thank you very much for your help!

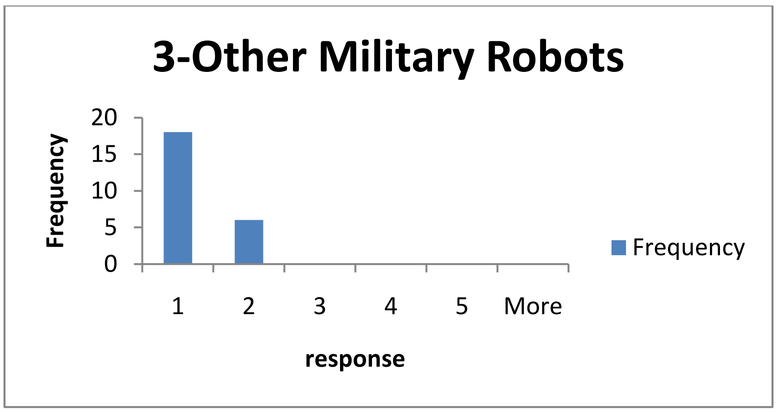
Appendix F: RICC Survey Results

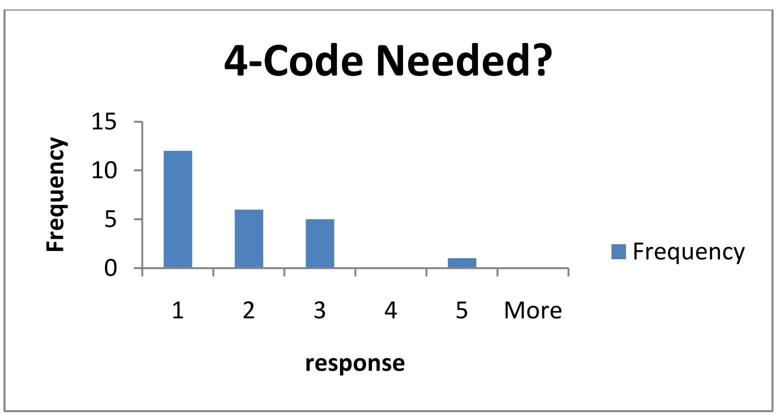
Survey #	1-a	1-b	1-c	1-d	1-e	1-f	2	3	4	5	6
1						hobby	2	1	1	1	1
2				1			3	1	1	4	4
3		1					2	1	2	2	5
4							1	1	1	3	3
5					1		4	1	1	4	5
6						military	2	1	1	1	4
7	1			1			4	1	5	1	4
8							1	1	1	4	1
9				1	1		2	2	3	3	3
10				1	1	hobby	2	1	1	1	5
11				1	1	battlebot	2	1	2	1	2
12				1	1	hobby	2	1	1	2	2
13					1		3	2	1	2	2
14					1		2	1	2	2	4
15		1		1	1		3	2	2	2	3
16		1		1	1		4	2	3	2	4
17	1	1		1			3	1	1	1	1
18				1			2	1	3	3	2
19				1	1	competition	2	1	2	2	2
20				1	1		3	1	3	3	5
21							4	2	3	2	4
22		1					2	1	1	1	1
23				1	1		2	1	2	3	2
24							2	2	1	5	1

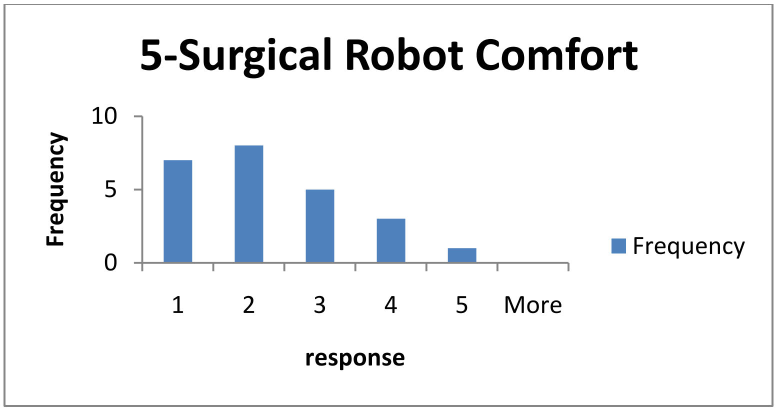
Histogram Key:

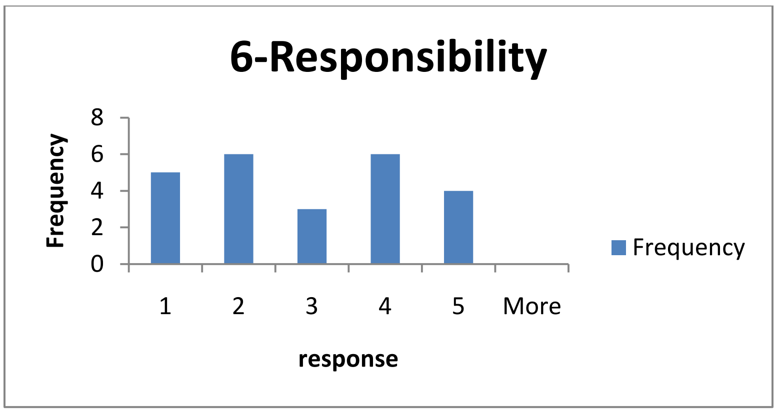
1	Strongly Agree
2	Agree
3	Indifferent
4	Disagree
5	Strongly Disagree


2-Armed Robots
Frequency
15
10
5
0
1
2
3
4
5
More
response
Frequency


3-Other Military Robots
Frequency
20
15
10
5
0
1
2
3
4
5
More
response
Frequency


4-Code Needed?
Frequency
15
10
5
0
1
2
3
4
5
More
response
Frequency


5-Surgical Robot Comfort
Frequency
10
5
0
1
2
3
4
5
More
response
Frequency


6-Responsibility
Frequency
8
6
4
2
0
1
2
3
4
5
More
response
Frequency

Appendix G: HRI Paper

A Code of Ethics For Robotics Engineers

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***Abstract*—The future of robotics engineering is in the hands of engineers and must be handled to ensure the safety of all people and the reputation of the field. We are in the process of developing a code of ethics for professional robotics engineers to serve as a guideline for the ethical development of the field. This document contains the current version of this code and describes the methodology used in developing it.**

Keywords: Robotics Engineering, Ethics, Code

I. Introduction

Professional engineers in disciplines such as electrical engineering, mechanical engineering and computer science have professional codes of ethics to provide guidance in their decision making. Robotics engineers are often able to find guidance from existing ethical codes, but also face unique ethical challenges, largely due to the combination of the autonomy of their creations and their creation's ability to interact directly with their environment, especially with humans. For this reason, we are in the process of developing a code of ethics for robotics engineers to help address their unique issues.

II. Methodology

Our first step in creating a code of ethics for robotics engineers was to research the fields of ethics and morality. Existing codes of ethics from the IEEE, ASME, and ACM were examined and used as guidelines for both format and content.

We discovered that although existing professional codes could provide some guidance to robotics engineers, none of these codes are sufficient on their own. The IEEE code of ethics, for example, is aimed at a very broad range of engineers and is therefore not specific enough for some of the issues in robotics engineering, particularly in addressing the additional forethought required by the autonomy of the engineer's creations. None of the existing codes we examined call upon engineers to take responsibility for the actions of their creations, i.e. robots.

One of the primary purposes of a code of ethics is to minimize the harm to all parties affected by the engineer's decisions and actions. To ensure that our code protects these parties, we created a list of communities to help engineers make ethical decisions. If a conflict arises between two communities in the list, decisions should be weighted in favor of the larger community.

We used an iterative approach to develop this code. We initially drafted some key points which we believed to be important for robotics engineers, and through discussions, added clarifications for these as well as other points as it became apparent that they were needed. We have continued to revise the code in this manner to improve clarity and to address additional situations and ethical problems. As one part of this iterative process, we created a list of situations with ethical implications which a robotics engineer may be expected to encounter, and evaluated each item in the list in terms of the draft code to make sure that the code covered them.

In order to encourage broad acceptance of the final product, many points of view need to be taken into consideration. We organized several focus groups concerning topics related to ethics in robotics engineering. For these focus groups we prepared questions in advance for the participants to discuss, with an emphasis on areas of responsibility, surgical robots, and military robots, both armed and unarmed.

We also distributed a survey concerning robots and the responsibilities of robotics engineers at the Robotics Innovation Competition and Conference (RICC) held at Worcester Polytechnic Institute in October of 2009. Insights from this survey and the discussion groups have been used to further refine the draft code of ethics.

The code will continue to be reviewed and refined until the completion of the project in February of 2010. More discussion groups will be held with groups both on and off campus so as to gather as much feedback as possible.

III. The Current Code of Ethics

A. Preamble

As an ethical robotics engineer, I understand that I have the responsibility to keep in mind at all times the well-being of the following communities:

Global – the good of as many people as possible and known environmental concerns

National – the good of the people and government of my nation and its allies

Local – the good of the people and environment of the community that is affected

Robotics Engineers – the reputation of the profession and colleagues

Customers – the expectations and the safety of the customer

Employers – the financial and reputational well-being of the company

B. Principles

To this end and to the best of my ability I will...

1- Recognize that I may be held responsible for the actions and uses of all creations in which I have a part.

It is the responsibility of a robotics engineer to consider the possible unethical uses of the engineer's creations to the extent that it is practical and to limit the possibilities of unethical use. An ethical robotics engineer cannot prevent all potential hazards and undesired uses of the engineer's creations, but should do as much as possible to minimize them. This may include adding safety features, making others aware of a danger, or refusing dangerous projects altogether. A robotics engineer must also consider the consequences of a creation's interaction with its environment. Concerns about potential hazards or unethical behaviors of a creation must be disclosed, whether or not the robotics engineer is directly involved. If unethical use of a creation becomes apparent after it is released, a robotics engineer should do all that is feasible to fix it.

2- Consider and respect not only peoples' physical well-being, but their rights as well.

A robotics engineer must preserve human well-being while also respecting human rights. The United Nations' Universal Declaration of Human Rights (http://www.un.org/en/documents/udhr/index.shtml) outlines the most fundamental of these rights. Privacy rights are especially of concern to a robotics engineer. A robotics engineer should ensure that private information is kept secure and only used appropriately. There are circumstances when honoring privacy rights or other rights conflict with preserving the well-being of an individual or group. In these cases, a robotics engineer must decide the ethical course of action, making sure the least harm is done.

3- Not knowingly misinform, and if misinformation is spread do my best to correct it.

A robotics engineer must always remain trustworthy by not misinforming customers, employers, colleagues or the public in any way. A robotics engineer must disclose when the engineer feels unqualified to safely or fully complete a required task. When others spread misinformation, a robotics engineer must do as much as possible to correct the misinformation.

4- Respect and follow local, national and international laws wherever applicable.

A robotics engineer must follow the laws of the applicable communities. This includes where the robotics engineer is working and the communities targeted by the outcome of the engineer's work.

5- Recognize and disclose any conflicts of interest.

A robotics engineer must disclose the existence of any conflicts of interest to employers. It is up to the robotics engineer to decide how to react to any such conflict, either by attempting to ignore personal feelings or by avoiding the source of conflict.

An employer must be aware of conflicts and that these conflicts of interest may affect the robotics engineer's decisions. Bribery inherently creates conflicts of interest and is unethical.

6- Accept and offer constructive criticism.

A robotics engineer should always strive to produce the best work possible and to help others to do the same. For this reason, a robotics engineer must both give and accept constructive criticism. This allows for robotics engineers to help improve each other's work, benefiting each other and those affected by the robotics engineer's work. A robotics engineer who refuses to consider criticism risks making avoidable mistakes.

7- Help and assist colleagues in their professional development and in following this code.

This code of ethics is available as a guideline for all robotics engineers as a means of uniting them with a common basis for ethical behavior. In following this code, a robotics engineer promotes the positive perception of the field by customers and the general public. In helping colleagues develop professionally and ethically, a robotics engineer makes sure that the field of robotics will continue to grow.

C. Conclusion

This code was written to address the current state of robotics engineering and cannot be expected to account for all possible future developments in such a rapidly developing field. It will be necessary to review and revise this code as situations not anticipated by this code need to be addressed.

IV. Future Development

We are continuing to host discussions and to modify the draft of the code as we discover omissions, problems or inconsistencies. We intend to continue to develop this code to increase its ability to be widely accepted as providing clear principles to encourage ethical behavior while not being too prohibitive to prevent wide adoption. We hope some version of this code will eventually be adopted by a professional organization of robotics engineers.

The most recent version of the code is available at http://users.wpi.edu/~dtjones/CodeofEthicsforRoboticsEngineers.pdf. If you have any questions or comments, please do not hesitate to contact us.

Acknowledgment

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