64. Roboethics: Social and Ethical Implications of Robotics

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The present chapter outlines the main social and ethical issues raised by the ever-faster application of robots to our daily life, and especially to sensitive human areas.

Applied to society in numbers and volumes larger than today, robotics is going to trigger widespread social and economic changes, opening new social and ethical problems for which the designers, the end user, the public, and private policy must now be prepared.

Starting from a philosophical and sociological review of the depth and extent of the two lemmas of robotics and robot, this section summarizes the recent facts and issues about the relationship between techno-science and ethics.

The new applied ethics, called roboethics, is presented. It was put forward in 2001/2002, and publicly discussed in 2004 during the First International Symposium on Roboethics.

Some of the issues presented in the chapter are well known to engineers, and less or not known to scholars of humanities, and vice versa. However, because the subject is complex, articulated, and often misrepresented, some of the fundamental concepts relating ethics in science and technology are recalled and clarified.

At the conclusion of the chapter is presented a detailed taxonomy of the most significant ethical legal, and societal issues in Robotics. This study is based on the Euron Roboethics Roadmap, and it is the result of three years of discussions and research by and among roboticists and scholars of Humanities. This taxonomy identifies the most evident/urgent/sensitive ethical problems in the main applicative fields of robotics, leaving deeper analysis to further studies.

Many roboticists, as well as authoritative scholars of the history of science and technology, have already labeled the 21st century as the *age of the robots*. Actually, in the course of the present century, intelligent autonomous machines will gradually substitute many automatic machines [64.1].

Humanity has built tools to increase its power by eliminating manual labor and needless drudgery. This factor has become one of the keys to successful economic progress, especially since the Industrial Revolution and the emergence of a mechanized economy, and even more so with the introduction of automatic machines in the 20th century [64.2].

Today, progress in the field of computer science and telecommunications allows us to endow machines with enough intelligence that they can act autonomously. Thus, we can forecast that in the 21st century humanity will coexist with the first *alien* intelligence we have ever come into contact with – robots.

A few years from now, many more fields of application will be robotized, because robotics will have occupied more territories. The figures of the annual *World Robotics Survey*, issued by the United Nations (UN) Economic Commission for Europe and the International Federation of Robotics (IFR), show a steady tendency for growth with the characteristic curve of a rapidly developing field, with short slowdowns and steep climbing.

Certainly, robotics is changing our way of living, working, and operating in the world.

While the application field of robots is widening, the robot is coming out of the factories and into our homes – it is becoming a consumer item. The robot – which was expected to be an extended, intelligent tool for the human – is becoming a partner and a companion [64.3].

Moreover, robotics is also changing our method of conducting scientific inquiry and perhaps even our concept of ourselves [64.4]. Synergies between robotics, neurosciences, medicine, education, and psychology, have broadened the scope of application of the latter, making robotics a platform of global scientific research on humankind, on our galaxy and on the interaction between humankind and nature [64.5].

When robotics is applied to society in numbers and volumes larger than today, it will trigger widespread social and economic changes, for which public and private policy must now be prepared [64.6].

It will be an event rich in ethical, social and economic problems.

In the next decades in the industrialized world – in Japan, South Korea, Europe, United States – humanoid robots will be among us, companions to the elderly and children, assistants to nurses, physicians, firemen, and workers. They will have eyes, human voices, hands and legs, skin to cover their gears, and brains with multiple functions. Often, they will be smarter and quicker than people they ought to assist. Placing robots in human environments inevitably raises important issues of safety, ethics, and economics.

What is going to happen when these smart robots are our servants and house stewards, and when our lives will depend on them?

Could people who mean no good use these robots to harm others?

The theme of the relationship between humankind and *autonomous* machines appeared early in world literature, developed firstly through legends and myths, then in scientific and moral essays. In early mythology, the ancient peoples expressed their worries about the disrupting power of machines over the old societies: when these artificial creatures to which we have given birth have learned everything from us, or understood that we are weaker than them, will they try to dominate us [64.7]?

In our time, facing the development of ever more powerful computers and the variety of humanoid robots, some scholars and scientists have warned about the dangers of the unlimited use of technology, and especially about the hubristic endeavor to design and manufacture intelligent creatures [64.8, 9].

Their concern has been amplified by the harsh discussion around bioengineering and bioethics. The famous physicist and Nobel prize winner Joseph Rotblat said that robotics, genetic engineering, and computer science are threatening the life on our plante [64.8, 9].

> *Thinking computers, robots endowed with artificial intelligence and which can also replicate themselves (...) this uncontrolled self replication is one of the dangers in the new technologies.*

Less dramatically, others have pointed out the need to introduce ethical rules in technological applications, especially regarding the behavior of intelligent machines. In this frame, the most matter-of-fact issue is: what will be the cultural and social implications of the robotics invasion? Could robots be dangerous to humankind in any way [64.10]?

Under the pressure of public opinion and the media, roboticists cannot avoid engaging in a critical analysis of the social implications of their researches, in order to be able to give *scientific and technical*, as well as *philosophical*, answers to questions such as:

- How far can we go in embodying ethics in a robot?
- What kind of *ethics* is robotic ethics?
- How contradictory is, on one side, the need to implement in robots an ethics, and, on the other, the development of robot autonomy?
- Is it right to talk about the *consciousness*, *emotions*, and *personality* of robots [64.11, 12]?

64.1 A Methodological Note

This chapter is by its nature somewhat different from – although complementary to – the remainder of this Handbook, because it deals not only with the scientific and technological issues inherent in the matter, but also with cultural and moral topics related to the introduction of robots in sensitive human areas.

The authors worked on the assumption that:

- This handbook – and in particular the present chapter – is going to be read by roboticists, and also by nonroboticists, by students of robotics as well as by students and scholars of ethics, philosophy of science, sociology, laws, etc. Some of the issues presented here are well known to some, and less or not known to the others, and vice versa. Nonetheless, the authors deemed it useful and important to recall and clarify some of the fundamental concepts relating ethics in science and technology, because the subject is complex, articulated, and often misrepresented.
- Roboethics is an applied ethics that refers to studies and works done in the field of science and ethics (science studies, science and technology studies (S&TS), science technology and public policy, professional applied ethics), and whose main premises are derived from these studies. In fact, roboethics was not born without parents, but it derives its principles from the global guidelines of the universally adopted applied ethics [64.13]. This is the reason why the substantial part of this Chapter is devoted to this subject, before specifically discussing the sensitive areas of roboethics.
- Many of the issues of roboethics are already covered by applied ethics such as computer ethics or bioethics [64.14]. For instance, problems arising in roboethics of dependability, technological addiction, the digital divide, the preservation of human identity and integrity [64.15]; the applications of precautionary principles, economic and social discrimination, artificial system autonomy and accountability, related to responsibilities for (possibly unintended) warfare applications [64.16]; and the nature and impact of human–machine cognitive and affective bonds on individuals and society have already been matters of investigation in the fields of computer ethics and bioethics [64.16].

The specificity of robotics is underlined from a general point of view. Subsequently, in the taxonomy herein, the specific ethical issues related solely to robotics are carefully evaluated. The present taxonomy is not developed on the basis of affinity to the techno-scientific or disciplinary areas – like the index of the present book. Rather, the roboethics taxonomy is based on the application areas of robots, and on the specificity inherent to the human–robot interaction of these applications [64.17].

In terms of scope, we have taken into consideration – from the point of view of the ethical issues connected to robotics – a temporal range of two decades, in whose frame we could reasonably locate and infer – on the basis of the current state-of-the-art in robotics – certain foreseeable developments in the field.

For this reason, we consider premature – and have only hinted at – problems related to the possible emergence of human qualities in robots: consciousness, free will, self-consciousness, sense of dignity, emotions, and so on. Consequently, this is why we have not examined problems – debated in some other papers and essays – like the proposal to not behave with robots like with slaves, or the need to guarantee them the same respect, rights, and dignity we owe to human workers.

Likewise, and for the same reasons, the target of roboethics is not the robot and its artificial ethics, but the human ethics of the robots' designers, manufacturers, and users.

Although informed about the issues presented in some papers on the need and possibility to attribute moral values to robots' decisions [64.18], and about the chance that in the future robots might be moral entities like – if not more so than – human beings [64.19], the authors have chosen to examine the ethical issues of the human beings involved in the design, manufacturing, and use of the robots.

The authors felt that problems such as those connected with the application of robotics within the military and the possible use of military robots against some populations not provided with this sophisticated technology, as well as problems of terrorism in robotics and problems connected with biorobotics, implantations, and augmentation, were pressing and serious enough to deserve a focused and tailor-made investigation. It is absolutely clear that, without a deep rooting of roboethics in society, the premises for the implementation of an artificial ethics in the robots' control systems will be missing.

64.2 Specificity of Robotics

Robotics is a discipline originating from:

- Mechanics
- Automation
- Electronics
- Computer science
- Cybernetics
- Artificial intelligence

but it draws on from several other disciplines:

- Physics/mathematics
- Logic/linguistics
- Neuroscience/psychology
- Biology/physiology
- Anthropology/philosophy
- Art/industrial design

Is robotics a new science? On one side, robotics could be regarded only as a branch of engineering dealing with intelligent, autonomous machines. In this case, it shares experiences with other disciplines, and it is somehow the linear sum of all the knowledge.

On the other side, it could be seen as a new science, in its early stage. Actually, it is the first time in history that humanity is approaching the challenge of replicating a biological organism in the form of an intelligent and autonomous entity. This extraordinary mission gives to robotics the special feature of being a platform where sciences and humanities are converging – an experiment in itself [64.20].

It is not without some grounds that we could forecast that robotics will emerge as a new science, with its own theory, principles, theorems, proofs, and mathematical language [64.21].

However, even before that, robotics displays a specificity, which compels the scientific community to examine closely many of the notions until now applied only to human beings.

Although the authors consider it premature to study scientifically the possible emergence in the robot of human functions, we do not exclude that in the future we will be confronted with problems that today we can only imagine through the work of the artists of the science fiction [64.22, 23].

64.3 What Is a Robot?

From the point of view of how today's society sees robots, we can say that robotics scientists, researchers, and the general public have different evaluations about robots, as described below.

64.3.1 Robots Are Nothing Else But Machines

Many consider robots as mere machines: very sophisticated and helpful ones, but always machines. According to this view, robots do not have any hierarchically higher characteristics, nor will the designer provide them with human/animal qualities. In this frame, the issues of the social and ethical implications of robotics fall into the categories of applying ethics to engineering.

64.3.2 Robots (and Technology in General) Have an Ethical Dimension

This derives from a conception according to which technology *is not an addition to man but is, in fact, one of the ways in which mankind distinguishes itself from animals*. So that, as language, and computers, but even more so, humanoids robots are symbolic devices designed by humanity to improve its capacity of reproducing itself, and to act with charity and good. "The humanoid (...) is the most sophisticated thinking machine able to assist human beings in manifesting themselves, and this is ethically very good, as it supposes a radical increment of human symbolic capacity; humanoids will develop a lot of activities in order to increase the human quality of life and human intersubjectivity" [64.24].

64.3.3 Robots as Artificial Moral Agents (AMA)

According to this concept, robots and artificial agents extend the class of entities that can be involved in moral situations, for they can be conceived as moral patients (as entities that can be acted upon for good or evil) and also as moral agents [64.25] (not necessarily exhibiting free will, mental states or responsibility, but as entities that can perform actions, again for good or evil) [64.13].

64.3.4 Robots: the Evolution of a New Species

In the United States, one of the main discussions in the field of ethics and robotics is how to consider robots, as only *objects* or *subjects* which deserve legal rights: robots, not slaves.

According to this point of view, not only will our robotics machines have autonomy and consciousness, emotions and free will, but also humanity will create machines that "*exceed us in the moral as well as the intellectual dimensions*. Robots, with their rational mind and unshaken morality, will be the new species: Our machines will be better than us, and we will be better for having created them" [64.26].

64.4 Cultural Differences in Robot's Acceptance

While we analyze the present and future role of robots in our societies, we shall be aware of the underlying principles and paradigms that influence social groups and individuals in their relationships with intelligent machines.

Different cultures and religions regard differently intervention in sensitive fields such as human reproduction, neural therapies, implantations, and privacy. These differences originate from the cultural specificities towards the fundamental values regarding human life and death.

In different cultures, ethnic groups, and religions the very concept of *life* and *human life* differ, first of all concerning the immanence or transcendence of human life. While in some cultures women and children have fewer rights than adult males (not even *habeas corpus*), in others the ethical debate ranges from the development to a post-human status, to the rights of robots. Thus, the different approach in roboethics concerning the rights in diversity (gender, ethnicity, minorities), and the definition of human freedom and animal welfare. From these concepts derive all the other ethical specificities such as privacy, and the border between privacy and traceability of actions.

Cultural differences also emerge in the realm of *natural* versus *artificial*: think of the attitude of different peoples towards surgical or organ implantation. How could human enhancement be viewed [64.27]?

Bioethics has opened important discussions: How is the integrity of the person conceived? What is the perception of a human being?

Last but not least, the very concept of *intelligence*, human and artificial, is subject to different interpretation. In the field of AI and robotics alone, there is a terrain of dispute – let us imagine how harsh it could be outside of the circle of the inner experts [64.4].

64.5 From Literature to Today's Debate

Literature is the instrument by which society expresses itself, free from rigid constraints, and by which it can *simulate* future social developments. Sometimes, by way of literature, important and foresighted scientific issues have been anticipated.

The topic of the threat posed by artificial entities designed by human's ingenuity (legends like *the rebellions of automata*, Frankenstein' myth, the Golem) recurs in classical European literature, as well as the misuse or the evil use of the product of engineering (the myth of Dedalus). This is not the case in all world cultures. For instance, the Japanese culture does not include such a paradigm; on the contrary machines (and, in general, human products) are always beneficial and friendly to humanity.

In 1942, the outstanding novelist Isaac Asimov, who coined the word *robotics*, formulated his famous three laws of robotics in his novel *Runaround*:

- Law 1: A robot may not injure a human being, or through inaction, allow a human being to come to harm.
- Law 2: A robot must obey the orders given it by human beings except where such orders would conflict with the first law.
- Law 3: A robot must protect its own existence as long as such protection does not conflict with the first or second law.

Later on, in 1983, Asimov added the fourth law (known as the zeroth Law).

- Law 0: No robot may harm humanity or, through inaction, allow humanity to come to harm [64.28, 29].

Although farsighted and forewarning, could these laws really become the *ethics of robots* or are they too *naïve* to be considered seriously in this debate?

Over the last few decades, scientific and technological developments have brought forward the frontiers of robotics, so that those problems that years ago seemed only theoretical, or a matter of literature and science fiction, are becoming very practical, and even urgent.

Some of these problems have alerted the robotics community on the need to open a discussion on the principles that should inspire the design, manufacturing, and use of robots.

In 2001, the collaboration between the roboticist Paolo Dario and the philosopher José Maria Galván expressed the concept of technoethics [64.30].

In the same year, on the occasion of Italy–Japan 2001 (Tokyo, Japan), Paolo Dario and Japanese roboticist Atsuo Takanishi organized the Workshop *Humanoids. A Techno-Ontological Approach*, which was held at Waseda University. The lecture given by Galvan was published in the December 2003 issue of IEEE Robotics & Automation Magazine, *On Technoethics* [64.24].

64.6 Roboethics

In 2002 the roboticist Gianmarco Veruggio, in the framework of the cultural and educational activity of the Association School of Robotics, started to discuss the need for an ethics which could inspire the work of robotics scientists. He called this new applied ethics, roboethics.

> *Roboethics is an applied ethics whose objective is to develop scientific/cultural/technical tools that can be shared by different social groups and beliefs. These tools aim to promote and encourage the development of Robotics for the advancement of human society and individuals, and to help preventing its misuse against humankind [64.31].*

According to the definition, roboethics is not the *ethics of robots*, nor any artificial ethics, but it is the human ethics of robots' designers, manufacturers, and users.

In January 2004, in Sanremo, Italy, the authors, in collaboration with roboticists and philosophers, organized the First International Symposium on Roboethics, where the word roboethics was officially used for the first time.

On this occasion Paolo Dario (RAS president 2002-03) and Kazuo Tanie (RAS president 2004-05) established a technical committee (TC) on roboethics, with the aims of providing the IEEE Robotics and Automation Society with a framework for analyzing the ethical implications of robotics

Fig. 64.1 The Roboethics' logo, sketched by the renowned Italian artist Emanuele Luzzati (1920 – 2007), is represented by a young smiling girl receiving a flower from a chivalrous humanoid robot

research, by promoting the discussion among researchers, philosophers, ethicists, and manufacturers, but also by supporting the establishment of shared tools for managing ethical issues in this context.

In 2005, the European Robotics Research Network (EURON) funded the project called the EURON Roboethics Atelier, with the aim of drawing the first roboethics roadmap. In 2006, in Genoa, Italy, scholars from humanities met for three days with engineers and roboticists to draw the lines of the EURON roboethics roadmap [64.17].

Roboethics is not a veto or a prohibitionist ethics. Its main lines of development are: the promotion of culture and information; the permanent education; a vigorous and straight public debate; and the involvement in all these activities of the young generations who are the actors of the future [64.32].

Now, it is worth analyzing briefly the general principle of ethics.

64.7 Ethics and Morality

> *Ethics is the branch of philosophy concerned with the evaluation of human conduct [64.33].*

The difference between ethics and morality is subtle. According to Italian philosopher Remo Bodei: "The word Ethics is generally associated to our relationship with others, to our public dimension; while morality concerns more with our conscience's voice, our relationship with ourselves. The distinction, however, is purely conventional, because the word comes from the Greek word *ethos*, which means habit, and morality from Latin *mos/moris*, which again means habit."

Another definition is the following:

> *In simple terms morality is the right or wrong (or otherwise) of an action, a way of life or a decision, while ethics is the study of such standards as we use or propose to judge such things [64.34].*

In short *morality* is the subject of a science called *ethics* (although *morality* may also refer to a code of conduct: see http://plato.stanford.edu/entries/morality-definition/) [64.35].

64.8 Moral Theories

Apart from *virtue ethics*, the classical Greek moral philosophy, the dominant moral theories are:

- *Utilitarianism* - or more generally *consequentialism*: guideline properties that depend only on the consequences, not on the circumstances or the nature of the act in itself;
- *Contractualism*: morality as the result of an imaginary contract between rational agents, who are agreeing upon rules to govern their subsequent behavior. The idea is not that moral rules have resulted from some explicit contract entered into by human beings in an earlier historical era, a claim that is almost certainly false. (John Locke seems to have held a view of this sort.) Nor is the idea that we are, now, implicitly committed to a contract of the *I will not hit you if you do not hit me* variety, which implausibly reduces moral motivation;
- *Deontologism*, or duty-based ethics. What is my moral duty? What are my moral obligations? How do I weigh one moral duty against another? Kant's theory is an example of a deontological or duty-based ethics: it judges morality by examining the nature of actions and the will of agents rather than the goals achieved.

In scientific circles, *secular humanism* – a nontheistically ethical philosophy based upon naturalism, rationalism, and free thought – has gained great importance and influence [64.36].

It is true that in the scientific and technological domain a professional conception of ethics, closer to professional deontology, is becoming dominant and a universal standard of practice.

Furthermore, ethics in the digital world needs new approaches, beyond the classical moral theories, opening new and unresolved moral problems.

64.9 Ethics in Science and Technology

In the last years, concerned scientists, stakeholders, nongovernmental organizations (NGOs), parents, and consumers associations have increased their influence on the development of the scientific and technological researches, proposing (often imposing) to scientists, manufacturers, distributors, and advertising agencies the adoption of ethical conducts. Sometimes their intervention was mild, other times it had the result of closing down wealthy lines of research.

That is one of the reasons why we cannot underestimate the impact of society's opinions on *science and society* issues, and on the trend of the advancement of science and technology.

How can ethical concerns and visions become practical rules of society [64.37]? How can the ethical principles discussed in transdisciplinary assemblies; expressed by warnings or the public's concern; suggested by religious personalities, theologians, and moral leaders; and/or forwarded by a community of concerned scientists modify research and development (R&D) [64.38]? How can ethical thrust be embodied in the R&D activity without imposing on it unjustified restrictions, so depriving the scientist of his/her own freedom of thought [64.39]?

Through the millennia of the history of science and technology, society has envisaged ways to express their ethical concern [64.40].

The professional *oath* is either a statement or a promise expressed by a new entry into professional careers to be faithful to the traditional values of the professional order he/she is entering in. The ancient *Hippocratic oath* is the recurrent example for other initiatives to develop and implement codes of conduct for scientists in general, and in specific areas in particular.

Otherwise, a *manifesto* is a public declaration of intentions, opinions, objectives or motives, often issued by a private organization or a government. For example, the Russell–Einstein Manifesto of 1955 is a public declaration against war and the further development of weapons of mass destruction.

A *statement* or a *declaration* can be employed to underline a given topic. As such, it can be either weakly or strongly prescriptive, morally or legally binding.

During the World Robot Conference which took place in Fukuoka, Japan, the participants released a three-part list of *expectations for next-generation robots*, called the *World Robot Declaration* issued on 25 February 2004. It states that:

- Next-generation robots will be partners that coexist with human beings;
- Next-generation robots will assist human beings both physically and psychologically;
- Next-generation robots will contribute to the realization of a safe and peaceful society.

A *recommendation* serves to induce acceptance or favor. It is a prescription only in the weak sense of offering advice: a normative suggestion that is neither legally nor morally binding. More conclusive is the *appeal*, an earnest request for support: a petition, entreaty, or plea.

A *resolution* is a formal expression of opinion or intention made (usually after voting) by a formal organization, legislature, or other group.

In the last 50 years, many professional associations have adopted their *code*: a written text that offers a collection of laws, regulations, guidelines, rules, directives or principles for moral conduct.

The *guiding principles* of the Code of Research Ethics are *non-malfeasance* and *beneficence*, indicating a systematic regard for the rights and interests of others in the full range of academic relationships and activities. *Non-malfeasance* is the principle of doing, or permitting, no official misconduct. It is the principle of doing no harm in the widest sense. *Beneficence* is the requirement to serve the interests and well being of others, including respect for their rights. It is the principle of doing well in the widest sense.

In the field of roboethics, the Government of Japan through the Ministry of Economy, Trade, and Industry has issued a *hugely complex set of proposals*, which is an articulated set of guidelines to ensure a safe deployment of robots in nonstructured environments. Under these guidelines, all robots would be required to report back to a central database any and all injuries they cause to the people they are meant to be helping or protecting. The draft is currently open to public comment with a final set of principles being made public in 2007. Among the indications:

> *Via a structure of general regulation and the adoption of that regulation, the planning, manufacturing, administration, repair, sales and use of robots shall observe the need for safety at every stage (...) The reasonably predictable misuse of robots shall be defined as the management, sale and use of next-generation robots for purposes not intended by manufacturers (...) There should, in principle, be no serious accidents such as fatal accidents involving*

robots, and the frequency of such accidents should be lowered as far as possible. Affordable multiple security measures should be taken in case one protection method alone is insufficient.

The *charter* is an ancient form of agreement. An example is the charter of the United Nations. Charters have a legal character and are connected, in principle, to sanctions when not properly executed.

In 2007, the Government of the Republic of Korea announced the birth of a governmentally sponsored working group whose aim is the definition of a roboethics charter.

The process towards the Korean Roboethics Charter is the following. The first step concerns the establishing of a working group (WG) on roboethics composed by robot developers, chief executive officers (CEOs), psychologists, futurists, writers, government officials, users, lawyers, and doctors. The WG will release a draft that will be circulated for feedbacks among online international communities, and through public hearings [64.41].

The revised draft will go for deliberation to the *Robot Industry Policy Forum*, which will be composed of 40 members, representing the main stakeholders. Subsequently, the draft will go to the *Industrial Development Council* (composed of 29 members). At this point – presumably at the end of 2007 – the draft becomes the Korean Roboethics Charter, and it will be officially announced. Then, application rules and detailed guideline will be released.

Other means of implementing ethical concerns in science and technology are the *convention*, a form of agreement, or a contract, and also a practice established by general consent.

Then, principles established by a government applicable to a people and enforced by judicial decision become *law*.

64.10 Conditions for Implementation

Once the chosen code of research ethics has been defined, a list of conditions for implementation should be drawn up. Actually, no regulation can be implemented without at least some of those conditions, which should favor the application of the rules.

From the *individual* scientist's point of view, he/she has to guarantee some conditions, without which he/she is not in the position to adhere to nor to implement the Code of Ethics. These are: decision-making capacity, that is the empowered position and freedom to identify and choose alternatives based on the values and preferences defined and accepted; individual scientists' honesty and integrity; and transparency of processes.

On the other side, the given scientific institution, and in the final analysis society, should guarantee the individual scientist the reasonable general framework in which he/she finds the best conditions to work. These are:

- Periodic review of the application procedures
- Review and assistance by ethics committees
- Promotion of public debate
- Definition of risk assessment, management and prevention
- Transnational practices: comparison of conducts across countries and comparisons of professional ethics around the world

64.11 Operativeness of the Principles

The implementation of regulations or of codes of conduct should provide guidelines for operationalizing and reconciling the principles to be implemented, in case such principles appear inherently contradictory.

For instance, ethical guidelines may – by virtue of their collective nature – pose a threat to the individual's moral autonomy. Or, the public's demand for accountability could threaten the professions' pursuit of autonomy.

64.12 Ethical Issues in an ICT Society

The importance of ethics in science and technology has been demonstrated by our recent history. Three of the front-rank fields of science and technology: nuclear physics, bioengineering, and computer science, have already been forced to face the consequences of their research's applications because of pressure caused by dramatic events, or because of the concern of the general public.

The introduction of intelligent machines in our daily life brings up global social and ethical problems which are usually summarized as

- dual-use technology (every technology can be used and misused)
- anthropomorphization of technological products (it is well known and documented that people attribute intentions, goals, emotions, and personalities to even the simplest of machines with life-like movement or form)
- humanization of the human–machine relationship (cognitive and affective bonds toward machines)
- technology addiction;
- digital divide, socio-technological gap (per ages, social layer, per world areas)
- fair access to technological resources
- the effects of technology on the global distribution of wealth and power
- the environmental impact of technology

Due to the interdisciplinarity of robotics, roboethics shares problems and solutions with other applied ethics: computer ethics, information ethics, bioethics, technoethics and neuroethics.

Computer ethics (CE), a term coined by Walter Maner in the mid 1970s, denotes the field of research that studies ethical problems *aggravated, transformed or created by computer technology*.

Perhaps the first contact between ethics and computer science took place in the 1940s, when Norbert Wiener, professor at the MIT and one of the founding fathers of computer science, expressed his concern about the social effects of the technologies he himself contributed to develop [64.42]. In 1948, in his book *Cybernetics: or Control and Communication in the Animal and the Machine*, and in his following book, *The Human Use of Human Beings*, he pointed out the dangers of nuclear war and the role of scientists in weapons development in 1947, shortly after Hiroshima. Although he did not use the term *computer ethics* he laid down a comprehensive foundation for computer ethics research and analysis. Wiener's foundation of computer ethics was far ahead of its time [64.43, 44].

It was not until 1968 that Wiener's concern became actual practice, when Donn Parker, one of the most famous scientist of the Stanford Research Institute (SRI) at Menlo Park, began to examine unethical and illegal uses of computers by computer professionals. He writes:

> *It seemed that when people entered the computer center, they left their ethics at the door.*

In 1968 he published his *Rules of Ethics in Information Processing* and promoted the development of the first code of professional conduct of the Association for Computing Machinery (ASM), which was adopted by the ACM in 1973.

During the late 1960s, Joseph Weizenbaum, the designer of the computer program Eliza, shocked by the emotional involvement of psychiatric scholars towards his simple programs, expressed his concern that an *information processing model* of human beings was reinforcing an already growing tendency among scientists, and even among the general public, to see humans as mere machines. Weizenbaum wrote the book *Computer Power and Human Reason*, in which he expressed his thoughtful ethical philosophy [64.45].

In the late 1970s, Walter Maner of the Virginia Old Dominion University was the first to employ the label *computer ethics* to define the field of inquiry dealing with ethical problems aggravated, transformed, or created by computer technology [64.46].

In 1985, James Moor of Dartmouth College published his article *What is Computer Ethics?* [64.47], and Deborah Johnson of the Rensselaer Polytechnic Institute published her book, *Computer Ethics*, the first textbook – and for more than a decade, the defining textbook – in the field. In 1983 the Computer Professional for Social Responsibility (CPSR) was founded at Palo Alto: a global organization promoting the responsible use of computer technology. Incorporated in 1983 (following discussions and organizing that began in 1981), CPSR is the first international association whose mission is to educates policymakers and the public on a wide range of issues [64.48].

In 1991 computer ethics was officially added as a subject to the programs in the computer science departments of the United States.

In the 1990s, it was proposed that the core of the issues of CE did not lie in the specific technology, but in the raw material manipulated by it (data/information), as a result of which several researchers (especially the team at Oxford led by Luciano Floridi) developed *information ethics* (IE).

Bioethics is the study of the ethical, social, legal, philosophical, and other related issues arising in health care and in the biological sciences (International Association of Bioethics, IAB) [64.49, 50].

In 1970 Van Rensselaer Potter (1911–2001) coined the term *bioethics* [64.50]. He was an American biochemist, Professor of Oncology at the McArdle Laboratory for Cancer Research at the University of Wisconsin, Madison. The first appearance of the term was in his book *Bioethics, A Bridge to the Future*. He coined it after trying for many months to find the right words to express the need to balance the scientific orientation of medicine with human values.

Potter's original concept of bioethics was comprised of a global integration of biology and values designed to guide human survival, with a new bioethics as the bridge between science and humanities. Increasingly, he felt the need to link what he came to realize had become mainstream biomedical ethics with environmental ethics.

During his career he continued to modify the term bioethics to differentiate his conceptions from the dominant view of biomedical ethics. He eventually selected the term global bioethics and this became the title of his second book [64.51]. In it, there is a new definition of the term bioethics, as *biology combined with diverse humanistic knowledge forging a science that sets a system of medical and environmental priorities for acceptable survival*.

The field of bioethics is at a critical stage of evolution, having now passed the 13th year of the development of bioethics programs. It is in a phase of professionalization attending to both the ethical framework for clinical and industrial bioethical consultation and the creation of the next level of academic organizational success, namely departments and PhD programs [64.52].

Technoethics is a recent definition, derived from Christian theology,

> *as a sum total of ideas that bring into evidence a system of ethical reference that justifies that profound dimension of technology as a central element in the attainment of a finalized perfection of man [64.53].*

Neuroethics is concerned with the ethical, legal, and social policy implications of neuroscience, and with aspects of neuroscience research itself [64.54]. Neuroethics encompasses a wide array of ethical issues emerging from different branches of clinical neuroscience (neurology, psychiatry, psychopharmacology) and basic neuroscience (cognitive neuroscience, affective neuroscience).

64.13 Harmonization of Principles

Internationally recognized institutions such as the United Nations, the World Health Organization (WHO), the Food and Agricultural Organization (FAO), the UN Educational, Scientific, and Cultural Organization (UNESCO)'s World Commission on the Ethics of Scientific Knowledge and Technology (COMEST), the International Labor Organization (ILO), the World Medical Association, the World Summit on the Information Society, and the European Union have identified general ethical principles that have been adopted by most nations, cultures, and people of the world.

Furthermore, the international scientific, juridical, economic, and regulatory community has on many occasions proposed a harmonization of world ethical principles applied to science and technology, especially in those cases when these principles involve sensitive issues such as life, human reproduction, human dignity, and freedom.

The Ethics of Science and Technology Programme, part of UNESCO's Division of Ethics of Science and Technology in the Social and Human Sciences Sector, and COMEST, an advisory body to UNESCO composed of 18 independent experts, have proposed, in the field of bioethics, to start a process towards a *declaration on universal norms on bioethics*. In Rio de Janeiro in December 2003, COMEST organized an international conference on the issue of a *universal ethical oath for scientists.*

In Europe, the 6th Framework Program, funded, under the Science and Society work Programme, the ETHICBOTS project (an abbreviation for merging technoethics of human interaction with communication, bionic, and robotic systems). The project aims to promote and coordinate a multidisciplinary group of researchers in artificial intelligence, robotics, anthropology, moral philosophy, philosophy of science, psychology, and cognitive science, with the common purpose of identifying and analyzing technoethical issues concerning the integration of human beings and artificial (software/hardware) entities. Three kinds of integration are analyzed:

1. Human–softbot integration, as achieved by AI research on information and communication technologies

2. Human–robot noninvasive integration, as achieved by robotic research on autonomous systems inhabiting human environments
3. Physical, invasive integration, as achieved by bionic research

64.14 Ethics and Professional Responsibility

Although ethics in science and technology is not limited to deontology or professional ethics, but concerns a broader range of questions involving the fundamental beliefs and moral principles, its results and conclusions become guidelines for conduct in professional daily life.

From the social and ethical standpoints, in deciding the design, development, and application of a new technology, designers, manufacturers, and end users should be following rules, which are common to all human beings:

- human dignity and human rights
- equality, justice, and equity
- benefit and harm
- respect for cultural diversity and pluralism
- nondiscrimination and nonstigmatization
- autonomy and individual responsibility
- informed consent
- privacy and confidentiality
- solidarity and cooperation
- social responsibility
- sharing of benefits
- responsibility towards the biosphere
- obligatory cost-benefit analysis (whether ethical issues are to be considered as part of a proper cost–benefit analysis)
- exploiting potential for public discussion

(the Charter of Fundamental Rights of the European Union, 2001 [64.55]).

Computer and information ethics has developed a codes of ethics called *PAPA* (an acronym of: privacy, accuracy, intellectual property, and access), which could be adopted by robotics. It is composed as follows.

- *Privacy*: What information about ones self or ones associations must a person reveal to others, under what conditions, and with what safeguards? What things can people keep to themselves and not be forced to reveal to others?
- *Accuracy*: Who is responsible for the authenticity, fidelity, and accuracy of information? Similarly, who is to be held accountable for errors in information and how is the injured party to be made whole?
- *Property*: Who owns information? What are the just and fair prices for its exchange? Who owns the channels, especially the airways, through which information is transmitted? How should access to this scarce resource be allocated?
- *Accessibility*: What information does a person or an organization have a right or a privilege to obtain, under what conditions, and with what safeguards?

Problems of the *delegation* and *accountability* to and within technology are problems of daily life for every one of us. Today, we give responsibility for crucial aspects of our security, health, life-saving, and so on to machines.

Professionals are advised to apply, in performing sensitive technologies, the *precautionary principle*:

> *When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause-and-effect relationships are not fully established scientifically.*

(*Source*: January 1998 Wingspread Statement on the Precautionary Principle; see also the Rio Declaration from the 1992 United Nations Conference on Environment and Development, Agenda 21; and the Commission of the European Communities, Brussels, 02.02.2000, com (2000) 1 communication from the Commission on the precautionary principle.)

From the precautionary principle other rules can be derived, such as:

- noninstrumentalization
- nondiscrimination
- Informed consent and equity
- Sense of reciprocity
- Data protection

All over the world, associations and orders of engineers have adopted codes of ethics guiding towards responsible conduct in research and practice. In this context, *security* and *reliability* are the most important ethical codes of conduct.

Among the other important recommendations are the following:

- Hold paramount the safety, health, and welfare of the public in the performance of their professional duties.
- Perform services only in areas of their competence.
- Issue public statements only in an objective and truthful manner.
- Act in professional matters for each client as faithful agents or trustees.
- Avoid improper solicitation of professional assignments.

(From the *American Council of Engineering Companies Ethical Guidelines*).

64.15 Roboethics Taxonomy

In this section we outline a first classification of the most evident ethical issues of robotics, based on the EURON roboethics roadmap.

Certainly, classifying the different branches of robotics is not an easy task. Likewise, it is a complex undertaking to organize a matrix of field of robotics/ethical issues. We have tried to classify these topics according to homogeneous fields from an applicative point of view.

Furthermore, in the present taxonomy, we have chosen the *triage process* of identify the most evident/urgent/sensitive ethical problems in robotics, leaving to other times and further studies more complex problems.

64.15.1 Humanoids

One of the most ambitious aims of robotics is to design an autonomous robot that could reach – and even surpass – human intelligence and performance in partially unknown, changing, and unpredictable environments.

Artificial intelligence will be able to lead the robot to fulfill the missions required by the end users. To achieve this goal, over the past decades scientists have worked on AI techniques in many fields, including:

1. Artificial vision
2. Perception and analysis of the environment
3. Natural language processing
4. Human interaction
5. Cognitive systems
6. Machine learning and behaviors
7. Neural networks

In this context, one of the fundamental aspects of the robots is their capability to learn: to learn the characteristics of the surrounding environment, that is, (1) the physical environment, but also (2) the living beings that inhabit it. This means that robots working in a given environment have to distinguish human beings from other *objects*.

In addition to learning about their environment, robots have to learn about their own behavior, through a self-reflective process. They have to learn from the experience, replicating somehow the natural processes of the evolution of intelligence in living beings (synthesis procedures, trying-and-error, learning by doing, and so on).

It is almost inevitable that human designers are inclined to replicate their own conception of intelligence in the intelligence of robots. In turn, the former gets wired into the control algorithm of the robots. Robotic intelligence is a learned intelligence, fed by the world models uploaded by the designers. It is a self-developed intelligence, evolved through the experience which robots have gained through the learned effects of their actions. Robotic intelligence also includes the ability to evaluate and attribute a judgment to the actions carried out by robots.

All these processes embodied in the robots produce a kind of intelligent machine endowed with the capability to express a certain degree of autonomy. It follows that a robot can behave, in some situations, in a way that is unpredictable to their human designers. Basically, the increasing autonomy of the robots could give rise to unpredictable and nonpredictable behaviors.

So, without necessarily imagining some science-fiction scenarios where robots are provided with consciousness, free will, and emotions, in a few years we are going to be cohabiting with robots endowed with self-knowledge and autonomy – in the engineering meaning of these words.

64.15.2 Artificial Body

Humanoids are robots whose body structure resembles the human one. They answer an age-old dream of humanity, and certainly do not spring only from rational, engineering, or utilitarian motivations, but also from psychoanthropological ones.

Humanoids are the expression of one of the demands of our European culture, that is, that humankind be the creator of some mechanical being in the shape of a human. In Japanese culture, it is the demand to carefully replicate nature in all its forms.

This is a very difficult and demanding enterprise, a project of the level of the mission to the moon. However, precisely because it is one of humanity's dreams, large investments are being made and progress is quick.

It has been forecast that in the not-so-distant future we will cohabit with humanoids whose shape will be so similar to that of human beings that it will render it possible to get mixed up in certain situations with the latter. Humanoids will assist human operators in human environments, will replace human beings, and will cooperate with human beings in many ways.

Given the high cost and the delicacy of the humanoids, they will probably be employed in tasks and in environments where the human shape would really be needed, that is, in all these situations where the human-robot interaction is primary, compared to any other mission – human-robot interactions in health care; children/disable people/elderly assistance; baby sitting; office clerks, museum guides; entertainers, sexual robots, and so on. Or, they will be employed as testimonials for commercial products.

The special tasks humanoid robots can fulfill are manifold. Humanoids are robots so adaptable and flexible that will be rapidly used in many situations and circumstances. They can assist humans to perform very difficult tasks, and behave like true and reliable companions in many ways. Their shape, and the sophisticated human–robot interaction, will be very useful for situations in which a human shape is needed.

The research carried out in humanoids laboratories throughout the world will have as a side-effect the development of a platform to study the human body, for training, haptic testing, and training, with extraordinary results for healthcare, education, edutainment, and so on [64.56].

Faced with an aging population, the Japanese society see humanoids robots as one way to enable people to continue to lead an active and productive life in their old age, without being a burden to other people.

From the point of view of *safety* in the use of humanoids, and taking into account that in the not distant future they will be used as companions to human beings, humanoids can rise serious problems related to the reliability of their *internal evaluation systems* and to the *unpredictability* of robots' behavior. Thus, designers should guarantee the traceability of evaluation/actions procedures, and the identification of robots.

Concerning safety, it should be underlined that an incorrect action by humanoids can lead to a dangerous situation for living beings and the environment. Furthermore, there could be also the case where the incorrect action by the robot is caused by a criminal intent, if robot's autonomy was controlled by ill-intentioned people, who modified the robot's behavior in a dangerous and fraudulent course.

Because humanoids combine almost all of the characteristics of the whole spectrum of robots, their use implies the emergence of nearly all of the problems we will examine below. In particular, their introduction into human environments, workplaces, homes, schools, hospitals, public places, offices, and so on, will deeply and dramatically modify our society.

There is already an important and well-documented literature on the implication of coexistence between human beings and humanoids. The problems range from the replacement of human beings (economic problems; human unemployment; reliability; dependability; and so on) to psychological problems (deviations in human emotions, problems of attachment, disorganization in children, fears, panic, confusion between the real and the artificial, feeling of subordination towards robots) [64.57].

On the technological and scientific side, trust towards and ever-greater autonomy of humanoids (and of the robots in general) are the dominant trends. From the ethical standpoint, many have expressed fear that too much autonomy can harm human beings. For instance, Japan's Ministry of Economy, Trade, and Industry are working on a new set of safety guidelines for next-generation robots. This set of regulations would constitute a first attempt at a formal version of the first of Asimov's science-fiction *laws of robotics*, or at least the portion that states that humans shall not be harmed by robots

Recently, Japan's ministry guidelines will require manufacturers to install a sufficient number of sensors to prevent robots from running into people. Lighter or softer materials will be preferred, to further prevent injury. Emergency shut-off buttons will also be required.

Another set of questions arises around the shape of the humanoids. Is it right that robots can exhibit a *personality*? Is it right that robot can express *emotion*? The concern expressed by psychologists is that, well before evolving to become conscious agents, humanoids can be an extraordinary tool used to control human beings.

In one of their papers, Wagner, Cannon, Van der Loos [64.58] list the main questions posed by the introduction of a new technology:

- Under what conditions should we decide that deployment is acceptable?
- At what point in the development of the technology is an increase in deployment acceptable?
- How do we weigh the associated risks against the possible benefits?
- What is the rate of the ethics of functional compensation or repair versus enhancement? This issue is especially notable regarding the problem of *augmentation*: In some cases a particular type of technology is regarded as a way of compensating for some function that is lacking compared to the majority of humans; in other cases, the same technology might be considered an enhancement over and above that which the majority of humans have. Are there cases where such enhancement should be considered unethical?
- Are there cases where a particular type of technology itself should be considered unacceptable even though it has the potential for compensation as well as enhancement?
- The question of identifying cause, and assigning responsibility, should some harm result from the deployment of robotic technology [64.59].

64.15.3 Industrial Robotics

An industrial robot is officially defined by ISO as an automatically controlled, reprogrammable, multipurpose manipulator.

Typical applications of industrial robots include welding, painting, ironing, assembly, pick and place, palletizing, product inspection, and testing, all accomplished with high endurance, speed, and precision.

Complexity can vary from simple single robot to very complex multirobot systems:

- Robotic arms
- Robotic work cells
- Assembly lines

From the social and economic standpoint, the benefits of these robots are extraordinary. They can relieve human beings of heavy work, dangerous workplaces, and routine and tedious activities.

In the future, we can imagine robotic factories, completely managed by robots. In the industrialized countries, which are facing a looming labor shortage due to their aging populations, robots in factories will cut costs.

Industrial robots increase productivity (higher speed, better endurance); they increase quality (precision, cleanliness, endurance); they make highly miniaturized devices possible (building the European Robotics Platform, EUROP).

Social problems stemming from the introduction of robots in factories are, first of all, loss of jobs and unemployment. On the other hand, while a welfare policy is to be implemented at a national level to facilitate workers' redeployment, and educational programs to create new skills, it should also be said that robots have also created new jobs directly and can create wealth, leading to the development of new industries and workplaces.

64.15.4 Adaptive Robot Servants

Robots come in several shapes and sizes (wheeled, legged, humanoids), equipped with different kinds of sensing systems (artificial vision systems, ultrasonic, radio) and manipulations (grippers, hands, tools, probes). Service robots support and back up human operators.

According the UN's annual World Robotics Survey issued by the UN Economic Commission for Europe (UNECE) and the International Federation of Robotics, 607,000 automated domestic helpers were in use at the end of 2003, two-thirds of them purchased during that year. The survey forecasts that the use of robots around the home – to mow lawns, vacuum floors and manage other chores – will increase year on year.

By the end of the decade, the study said, robots will *not only clean our floors, mow our lawns and guard our homes but also assist old and handicapped people with sophisticated interactive equipment, carry out surgery, inspect pipes and sites that are hazardous to people, fight fire and bombs*.

Servant robots can: clean and housekeep; they are fast and accurate, and never bored. They can babysit, because they are patient, talkative, and able to play many games, both intellectual and physical. They can assist patients, the elderly, and the handicapped in clinics or at home, being always available, reliable, and taught to provide physical support.

Certainly, servant robots can guarantee a better quality of life, providing that designers guarantee safety and security (unpredictability of machine behavior from machine learning; assignment of liability for misbehavior or crime).

From a social and psychological standpoint, overuse could lead to technology addiction or invasion of privacy. Humans in robotized environments could face psychological problems [64.60].

64.15.5 Distributed Robotic Systems

The fast growth of the many wireless systems makes it possible to link all robots to the Web. Network robotics will allow remote human–robot interaction for teleoperation and telepresence, and also robot–robot interaction for data sharing, and cooperative working and learning. When Web speed become comparable to that of the internal local-area network (LAN) of the robot, the machine will explode into a set of specialized systems distributed over the net.

Complex robotic systems will be developed, constituted by a team of cooperating robotic agents/components connected through information and communication technology (ICT) and GRID, on distributed computing, technologies:

- Networked knowledge system
- Networked intelligence systems
- Multirobot systems

Multirobot systems are self-organizing robot teams consisting of a large number of heterogeneous team members. The organization in robot teams or squads is needed to perform specific tasks that require automatic task distribution and coordination at a global and local level, and when central control becomes impossible due to large distances and the lack of local information, or when signal transmission delays.

A full-scale robot team would be of tremendous value in a number of applications such as security, surveillance, monitoring, gardening, and pharmaceutical manufacturing. In addition, the coordination of heterogeneous teams of robots will also be of significant value in terms of planning, coordination, and the use of advanced manufacturing systems.

The benefits of robot teams are manifold, including increases in efficiency in performing complex tasks, and the capability to manage large-scale applications. They also provide abundant and replaceable interchangeable agents, which improves the reliability because the group can perform even after losing most of its parts.

On the other side, scientists should be aware of some of the risks in applying robot teams, for instance, the increasing dependability of primary services from complex systems, and the unpredictability of robot team behavior. From a criminal point of view the assignment of liability for misbehavior or crimes, vulnerability to hacking, and concerns about privacy are some of the important issues.

64.15.6 Outdoor Robotics

Outdoor robots are intelligent machines that explore, develop, secure, and feed our world. Robots could also be employed in dangerous operations such as laying explosives, going underground after blasting to stabilize a mine roof, and mining in areas where it is impossible for humans to work or even survive.

They can work in the following environments:

Land

- Mining (automated load–haul–dump trucks, robotic drilling and blasting devices)
- Cargo handling (cranes and other automation technology for cargo lift on/lift off)
- Agricultural (autonomous tractors, planters and harvesters, applicators for fertilizers and pest control)
- Road vehicles (autonomous vehicles for humans or cargo transportation)
- Rescue robotics (robots that support first-response units in disaster missions)
- Humanitarian demining (robots for detecting, localizing, and neutralizing landmines)
- Environmental protection (robots for pollution cleaning and decommissioning of dangerous facilities).

Sea

- Research (marine robots for oceanography, marine biology, geology)
- Offshore (underwater robots for inspection, maintenance, repair and monitoring of oil and gas facilities in deep and ultradeep waters)
- Search and rescue (underwater robots for first-response intervention in case of accidents at sea, such as a submarine that has run aground).

Air

- UAV (autonomous airplanes for weather forecasting, environmental monitoring, road traffic control, large-area survey, and patrolling).

Space

- Space exploration (deep-space vehicles, landing modules, rovers)

- Space stations (autonomous laboratories, control and communication facilities)
- Remote operation (autonomous or supervised dexterous arms and manipulators)

Mobile robots in particular can be highly valuable tools in urban rescue missions after catastrophes such as earthquakes, bomb or gas explosions, or everyday incidents such as fires and road accidents involving hazardous materials. Robots can be used to inspect collapsed structures, to assess the situation and to search and locate victims.

Among the benefits of employing such robots is the increased efficiency of the exploitation of natural resources, which could increase food production for the world's population.

Concerning space robotics, it is obvious that, on the basis of current knowledge and technology, the robot can be our pioneer in space travel and missions to explore the far planets of the solar system and beyond.

On the social front, the unrestrained use of outdoor robots could extend the excessive anthropization and exploitation of the planet, which can become in turn a threat to biodiversity and all other forms of life on the planet. As for AI, the other branch of robotics, this could lead to technology addiction. Furthermore, given the versatility of these robots, they can be converted from civilian use for warfare and misuse (terrorism, pollution).

64.15.7 Surgical Robotics

The field of surgery is entering a time of great change, spurred on by remarkable recent advances in surgical and computer technology. Computer-controlled diagnostic instruments have been used in the operating theater for years to help provide vital information through ultrasound, computer-aided tomography (CAT), and other imaging technologies. Recently robotic systems have made their way into the operating room as dexterity-enhancing surgical assistants and surgical planners, in answer to surgeons' demands for ways to overcome the surgical limitations of minimally invasive laparoscopic surgery, a technique developed in the 1980s. On 11 July 2000, the Food and Drug Administration (FDA) approved the first completely robotic surgical device.

Typical applications are:

- Robotic telesurgical workstations
- Robotic devices for endoluminal surgery
- Robotic systems for diagnosis (Cat Scan - Computerized Axial Tomography Scan; NMR, Nuclear magnetic resonance; PET - Positron emission tomography)
- Robots for therapy (laser eye treatment, targeted nuclear therapy, ultrasonic surgery, etc.)
- Virtual environments for surgical training and augmentation
- Haptic interfaces for surgery/physiotherapy training

64.15.8 Biorobotics

Biorobotics comprises many different but integrated field of researches. Among them, the design and fabrication of novel, high performance bio-inspired machines and systems, for many different potential applications. The development of nano/ micro/ macro devices that can better act on, substitute parts of, and assist human beings - in diagnosis, surgery, prosthetics, rehabilitation and personal assistance. The development of devices for biomedical applications (e.g. mini-invasive surgery and neuro-rehabilitation).

> *Biorobotics is a new scientific and technological area with a unique interdisciplinary character. It derives its methodology mainly from the sectors of robotics and biomedical engineering, but also includes knowledge from, and provides useful applications to, many sectors of engineering, basic and applied sciences (medicine, neuroscience, economics, law, bio/nanotechnologies in particular), and even the humanities (philosophy, psychology, ethics).*
> *Biorobotics offers a new paradigm for engineers. The engineer no longer just cooperates with neuroscientists, but has also become a scientist in order to discover basic biological principles that make their job easier [64.61].*

64.15.9 Biomechatronics

Human prostheses for locomotion, manipulation, vision, sensing, and other functions include:

- Artificial limbs (legs, arms)
- Artificial internal organs (heart, kidney)
- Artificial senses (eye, ears, etc.)
- Human augmentation (exoskeleton)

This field has an important connection with neuroscience, to develop neural interfaces and sensory-motor coordination systems for the integration of these bionics devices into the human body/brain.

64.15.10 Health Care and Quality of Life

Health care and quality-of-life robotics is certainly a very promising field, where progress will be directly measured by the well being of people. It is also the best way to promote robotics among the public, especially amongst aging populations.

Surgical robotics allows minimally invasive surgery, which can reduce patient recovery time, and may also improve accuracy and precision. Robotics systems increase the precision of microsurgery and enhance the performance of complex therapies. Surgical robots can restore a surgeon's dexterity. Robotic surgery is also applied to very delicate neurological procedures that are practically impossible to perform without robotic assistance.

Assistive technology will help many people to conduct a more independent life.

Biorobotics, while enhancing the quality of life after diseases or accidents, provides tools for studying biological behavior and brain functions, and is a test bed for the study and evaluation of biological algorithms and modeling.

From the social and ethical standpoint, this is one of the fields in robotics that suffers from the most difficult safety and ethical problems. From a technical point of view, scientists in robotic surgery are working on the problems of reduced dexterity, workspace, and sensory input and possible fatal trouble, which could originate from the breakdown of surgical robot systems. Issues of size, cost, and functionality should also be addressed in surgery, haptic, and assistive robotics.

In the context of assistive technology, some questions concerning the relationship between patients and the health structures in which they are treated can be posed. Are we going to mechanize hospitals and to dehumanize our patients? Shall we improve our health structures, where human nurses can care for patients? May we not develop new psychological and physical dependences?

As a general principle of awareness, we should underline that the high cost of robotic systems in the medical field could widen the digital divide between developed and developing countries, and between layers of the same population.

The field of implantations raises concerns related to the fact that direct brain interfaces may at the same time pose ethical questions related to the enhancement of human function.

The BioX program at the University of Stanford, and the Stanford Center for Biomedical Ethics, funded a pilot study in this domain called cross-cultural considerations in establishing roboethics for neuro-robot applications [64.62, 63]. This study explores funding mechanisms to investigate the span of ethical issues currently confronting direct brain interface investigators, how different kinds of interfaces may indicate different approaches to bioethics, and how other stakeholders in the deployment and use of this technology (for example, from law, government, and healthcare provider professions) perceive the relative importance of the various bioethics issues for the variety of interfaces that currently exist and those on the horizon.

64.15.11 Military Robotics

Intelligent Weapons

This field includes all devices resulting from the development of traditional military systems using robotics technology (automation, artificial intelligence, etc.):

- Integrated defense systems: an AI system for intelligence and surveillance, controlling weapons and aircraft capabilities
- Autonomous tanks: armored vehicles carrying weapons and/or tactical payloads
- Intelligent bombs and missiles
- Unmanned aerial vehicles (UAVs): unmanned spy planes and remotely piloted bombers
- Autonomous underwater vehicles (AUVs): intelligent torpedoes and autonomous submarines

Robot Soldiers

Humanoids will be employed to substitute humans in performing *sensitive* tasks and missions in environments populated by humans. The main reasons for using humanoids are to permit a one-by-one substitution, without modifying the environment, the human–human interaction, or the rules of engagement. This could be required where safeguarding human life is considered a priority in many different scenarios:

- Urban terrain combat
- Indoor security operations
- Patrolling
- Surveillance

Outdoor security robots could be able to make their night watch rounds and even chase criminals, directed by a remote-control system via an Internet connection or moving autonomously via their own artificial intelligence systems.

Superhumans

There are several projects aimed at developing a superhuman soldier. Actually, the human body cannot perform a task with the same strength, speed, and fatigue resistance as machines. Robotic *augmentation* describes the possibility of extending existing human capabilities through wearable robot exoskeletons, to create superhuman strength, speed, and endurance, including applications such as:

- artificial sensor systems
- augmented reality
- exoskeletons

The benefits of military robots are:

1. tactical/operational strength superiority
2. unemotional behavior, potentially more ethical than humans
3. limiting the loss of human lives in the robotized army
4. better performance of superhuman over human soldiers

Problems could arise from:

1. the inadequacy to manage the unstructured complexity of a hostile scenario
2. the unpredictability of machine behavior
3. the assignment of liability for misbehavior or crimes
4. the increased risk of starting a videogame-like war, due to the decreased perception of its deadly effects

From the human point of view, humans in mixed teams could face psychological problems, such as the practical and psychological problems of having to distinguish between humans from robots and the stress and dehumanization of superhuman soldiers.

In 2007, the Georgia Tech Mobile Robot Lab – lead by Ronald Arkin – led an online *opinion survey on the use of robots capable of lethal force in warfare*. the opinion survey is part of an important research project under a grant from the Army Research Office. The goal of this survey was to determine how acceptable the robots capable of lethal force in warfare are to different people of varying backgrounds and positions.

Military robotics should be thoroughly examined by specialized international organizations, as happens for every type of military technology, to be regulated by international conventions or agreements [64.64].

64.15.12 Educational Robot Kits

The beneficial applications of robotics in education are known and documented.

Robotics is a very good tool for teaching technology (and many other subjects) whilst, at the same time, always remaining very tightly anchored to reality. Robots are real three-dimensional objects which move in space and time, and can emulate human/animal behavior; but, unlike video games, they are real machines, true objects, and students learn much more quickly and easily if they can interact with concrete objects as opposed to formulas and abstract ideas.

In the age of electronics, computers, and networks, it is necessary to modernize not only educational content and tools, but also the methods used in traditional schools.

It is also important to consider that the lifestyle of young people has changed as well as the communication tools they use in their free time. Today, young people communicate via the Internet and mobile telephones using e-mail, SMS, and chat rooms, which allow them to be continually connected to a global community that has no limits regarding location and time.

Young people spend more time playing videogames, playing with their mobile phones or downloading files from the Internet. These activities provide them with experiences that are by now at the same standard as the most sophisticated technological systems. All this has accelerated the pace of life; so much so that fruition and consumption of experiences are both real and virtual. In fact, we are entering the age of cyberspace, which will not replace normal life relationships, but will certainly alter their characteristics.

In this context, we need to consider that traditional teaching and classical tools of support (books, documentaries) are at risk of becoming unsuitable when compared with the everyday possibilities offered to these young people by the world of mass media. Therefore, it is necessary to begin to plan new ways to transmit knowledge which exploit the potential of this new technology.

Learning about robotics is important not only for those students who want to become robotics engineers and scientists, but for every student, because it provides a strong method of reasoning and a powerful tool for grappling with the world. Robotics collects all the competencies needed for designing and constructing machines (mechanics, electrotechnics, electronics), computers, software, communications systems, and networks. The special features of robotics boost student creativity, communication skills, cooperation, and teamwork.

Learning about robotics promotes students' interest in and commitment to traditional basic disciplines (mathematics, physics, technical drawing). Robotic construction kits, which can combine the physical building of artifacts with their programming, can foster the development of new ways of thinking that encourage new reflections on the relationship between: (1) life and technology, (2) science and its experimental toolset, and (3) robot design, and values and identity.

64.15.13 Robot Toys

The Aibo robot is the Sony's robotic puppy dog with a software-controlled personality and abilities. The entertaining robot, which costs upwards of $2000, can dance, whimper, guard, and play, developing personalities based on interaction with its owners. Sony has sold over 150 000 Aibos since launching the product in May 1999.

Company officials said that there was a real effort this time to make the Aibo's movements more doglike; designers even studied the way dogs move. Developers replaced a relatively un-dog-like sideways head motion of one motor (as with the previous model, there are 20 motors) with a sort of forward-and-down movement.

Robot toys can be intelligent toys: they can be specifically designed to stimulate children's creativity and the development of their intellectual faculties. They can become children's companions, and – for only children – could play the role of *friends*, *brothers*, or the traditional *imaginary fiend*. They could also be used in the pedagogical assistance of autistic children.

On the negative side of technology, robot toys could cause psychological problems, such as:

- lost touch with the real world
- confusion between the natural and the artificial
- confusion between the real and the imaginary
- technology addiction [64.65]

64.15.14 Entertainment Robotics

Robots will enable the construction of real environments that could either be the perfect (or scaled) copies of some existing environments, or the reconstruction of settings existed centuries/millennia ago, and which we can populate with real or imaginary animals.

Robots and robotics settings will make it possible to build natural phenomena and biological processes, even cruel ones, without involving living beings.

In these settings, the users/audience could live interactive experiences, which are *real*, not only *virtual*.

As extraordinary theatrical machines, robots will develop ever more *real* special effects.

Entertaining robots are already used to display and advertise corporate logos, products, and events. These are marketing tools showed off by the manufacturers on special occasions.

In this framework, we should also consider sexual robots, which will be an important market. They could be used as sexual partners in many fields, from therapy to prostitution, and their use could decrease sexual exploitation of women and children [64.66]. This also raises issues related to intimacy/attachments, and about safety and reliability.

64.15.15 Robotic Art

The role of robotics in contemporary art, along with all the types of interactive artistic expressions (telecommunications, and interactive installations), is gaining importance and success.

Artists are employing advanced technologies to create environments and works of art, utilizing the actuators and sensor to allow their robots to react and change in relation to viewers.

Robotic art will spread because:

- It recalls (and it is inspired by) the mythological traditions of various cultures. These traditions have created fantastic synthetic creatures;
- Robots exert on the population at large a special fascination;
- Robots can be used as tools in artwork and enable the building of artistic expression in shorter times, thus expanding the borders of human creativity;
- Robots can also perform actor's rules and allow playing living art.

The social and individual problems that can be produced by robotic art are, on the one hand, the dissemination of misinformation (by spreading of false information using technology), while on the other hand, technology may prevail over creativity.

64.16 Conclusions and Further Reading

In this chapter we have analyzed the main social and ethical issues in robotics, five years after the birth of roboethics, and after three years of wide and intense international discussion. In the conclusions, we develop some assessments, foresee lines of progress, and five some indications for those who wish to study the subject of roboethics in more depth.

The so-called robotics invasion has not yet been unleashed. Surely, the recent figures of the World Robotics Report (Unece/Fir 2005) show a steady growing trend of the robotics production and sales. However, often the media demand more inventions and *gadgets* from the robotics laboratories than the laboratories can afford and, looking at the many automatons that are still struggling to walk, the latter's efforts have so far proved to be something of a disappointment. This is certainly a problem and a pressure for the robotics scientists. For the time being, robotics is a field of research and development that can be applied in, and depends, a high level of technology.

However, we are witnessing a true, growing interest in robots from the general public, who are often more excited than the insiders, whose feelings swing between a position of cultural indifference to a behavior dictated by external pressures, be they political or industrial. We are also noticing the modern change – which had already happened in the 1970s in the field of computer science – of the transformation of the robot from a research platform and a working tool to a consumer item, and an object of entertainment. This is a juvenile phenomenon, as shown by the increase of robotics contests among high-school students. Today's young people who are getting their hands on robotics kits will be the robotics professionals and consumers of tomorrow.

Growing interest in the social effects of robotics is easy to observe among international professional associations and orders, stretching over the sister fields of computer ethics and bioethics.

Certainly, roboethics is still far from being a well-established applied ethics, and by *well established* authors mean that it should demonstrate two qualities: to be universally accepted and standardized, or at least adopted by some communities, relevant in size and in political/economic/cultural influence, and to be embodied in the design, production, and use of robots.

In this chapter, we have mentioned two important steps in this general direction: the guidelines for the use of robots in the human environment, drawn up by the ad hoc group of the Japanese METI; and the Roboethics Charter, which is still in progress, being edited by the appointed committee of the Republic of South Korea. We should recall a few other projects that are studying the effects of the application of robotics to the neurosciences [64.58] and to bioethics/biorobotics [64.67,68]. However, there is no question that we are still at an initial stage of the subject's development.

In fact, considering the history of the two widely applied and structured ethics which are extensively studied and which reach a certain organic unity, bioethics and computer and information ethics [64.46], we acknowledge that their development, which has been happening for over 30 years, came about through leaps and contradictions, chasms and bends, and that they are far from being a suitable ethical standard shared by a plurality of subjects. Both these ethics were born in a policy and legislative vacuum, as technological changes outpaced ethical developments, bringing about unanticipated problems [64.47].

The standardization of roboethics requires the accomplishment of some fundamental steps, both culturally and institutionally. From the general standpoint, it demands that the application of robotics to the human environment, especially to sensitive areas of the human life, will be accepted by the quasi totality of cultures, as has happened with other techno-scientific innovations such as electricity and computer systems. (In the case of free access to the Internet, the issue is still questionable in many nations.) Should this be achieved, roboethics would have already passed the phase of being adjusted to fit different answers and situations, to being modified to the point of having acquired the capability of adapting to different points of views. Different cultures and religions regard the intervention in sensitive fields such as human reproduction, neural therapies, implantations, and privacy differently. These differences originate from cultural specificities regarding fundamental issues, for example, the limit between a human and a cyborg; the separation between the natural and the artificial; the difference between human and artificial intelligence; the border between privacy and the traceability of actions; the concept of integrity and the unity of the human being; the acceptance of diversity (in gender, ethnicity, minorities, etc.); the boundary between replacement and human enhancement; and so on [64.49]. These are all milestones in defining the underlying paradigms, which in turn influence the day-by-day behavior of everyone.

There are many different aspects to be looked at, for instance, in some cultures the reproduction of the human figure is forbidden. In others, the difference between human and nonhuman is not so sharp. The application of humanoid robots should be set against this background [64.69]. The diversity of ideas on these issues, such as natural versus artificial or animate versus inanimate, has immediate effects on the field of organ transplants, and subsequently of robotic organ implants. As a matter of fact, the debate on human enhancement versus rehabilitation is very active in Europe and the United States, for the time being mainly in the field of bioethics.

From the experience provided by more than 30 years of discussions and disputes in the fields of bioethics and information ethics, we know that all the achievements in the field of science and ethics are neither easy nor negligible.

For those who wish to thoroughly investigate some elements of philosophy of science; of history of science and ethics; of science and engineering's ethics; of the law applied to science and technology, we now suggest some fundamental steps.

In the field of the moral theories related to science and technology, we mention the considerable work of Tom L. Beauchamp from the Kennedy Institute of Ethics [64.49].

Two important annual gatherings of Computer Philosophy, CEPE, Computer Ethics Philosophical Enquiry and IACAP International Association for Computing and Philosophy, to mention just two, have recently added *roboethics* as one of their key topics.

We also encourage students and scholars to consult the works and website of the renowned Center for Computing and Social Responsibility (CCSR) of DeMontfort University, Leicester, UK. The CCSR is internationally recognized for its applied research expertise on the risks and opportunities of information technology. It also organizes the International Conference on the Social and Ethical Impacts of Information and Communication Technology (ETHICOMP) every year.

Furthermore, it is very useful to follow the activity of the regulatory bodies entitled to deal with the issues of science and ethics. In accordance with what was said in Sects. 64.4, 64.5, 64.12, and 64.13 of this chapter, the person's interest should start from the general principles that are essentially accepted by most of the worlds' Nations (at least, nominally), and to come down to the specific applications in our field.

The Ethics of Science and the Technology Programme is part of UNESCO's Division of the Ethics of Science and Technology in the Social and Human Sciences Sector. COMEST is an advisory body to UNESCO. The two bodies work to apply in science and technology the principles of the Universal Declaration of Human Rights.

The Unesco's Ethics of Science and Technology Programme was created in 1998 along with COMEST to provide ethical reflection on science, technology, and their applications. Currently, in accordance with Decision 3.6.1 of the 169th session of the Executive Board, UNESCO is initiating standard-setting action by drafting studies on some new technological areas.

Another body whose activity is useful to follow is the European Group on Ethics in Science and New Technologies and the Forum (EGE, European Group on Ethics in Science and New Technologies), established by the European Commission. The EGE is an independent, pluralist and multidisciplinary body that advise the European Commission on ethical aspects of science and new technologies, regarding the preparation and implementation of community legislation or policies. The forum has many complementary roles. The former body is appointed to provide high-level specialist ethical advice to the European Commission, particularly in relation to the policy arena. The latter was set up under the Framework Programme as a networking activity with the aim of sharing information and exchanging best practices on issues of ethics and science. They work on the basis of the Lisbon Declaration 2000 and the charter of fundamental rights of the European Union approved by all the member states in 2001 (Nice, France).

Concerning the role of science and technology in law, politics, and the public policy in modern democracies, there are important differences between each of the European, the American, and the – we could say – oriental approach. In the United States, the general attitude is definitely more science-based than it is in Europe. In the former case, science is said to speak the truth, and the regulatory process is based more on objective scientific data than on ethical considerations. At the same time, the subjective point of view is taken up by the courts, which are now also intervening directly in areas such as risks to society and scientific knowledge, although the current conceptual tools of jurisprudence in the field of science and technology are still very limited. Nonetheless, in the Anglo Saxon culture, *law does not speak the language of science* [64.70].

On the other hand, in Europe, against the backdrop of the ongoing process of European cohesion, regulation and legislation of science and technology is assuming the character of the foundation of a new political community – the European Union – which is centered around the relationship between science and its applications, and the community formed by the scientists, technology producers, and citizens. We can safely assume that, given the common classical origin of jurisprudence, the latter process could be helpful in influencing other cultures, for instance, the moderate Arab world.

On the subject of science, technology, and law in America and Europe, we recommend the impressive work by Sheila Jasanoff (Kennedy School of Government Faculty, Harvard University) whose research pivots on the role of science and technology in the law, politics, and public policy in Europe, the United States, and India, with particular reference to the behavior of the American courts in the regulation of science, and to the role of experts.

There is a third way to approach issues in science and society, which could be called oriental. In fact, in Japan and in the Republic of South Korea, issues of robotics and society have been handled more smoothly and pragmatically than in Europe and in America. Due to the general confidence from these societies towards the products of science and technology, the robotics community and the ad hoc ethical committees inside these governments have started to draw up guidelines for the regulation of the use of robotic artefacts. This nonideological nonphilosophical approach has its pros and cons, but it could encourage scientists and experts in Europe and the United States to adopt a more normative position.

For those who are interested in keeping up to date on these issues, a good habit to acquire is to consult the archives and websites of the academic institutions, private associations, and professional orders where problems of science and ethics are followed on a regular basis. The Nobel Prize Pugwash Conference for World Affairs is the umbrella association for this community and NGOs concerned with these issues. The IEEE Robotics & Automation Society's Technical Committee on Roboethics was formed for the purpose of promoting and collecting research on robotics and society.

The issue of the influence and the pressure provided by the market on science and R&D is handled by applied ethics, and is known as business ethics. In this framework, corporate social responsibility is one of the ways in which enterprises can affirm ethical principles and values. This view was introduced to the United States 15 years ago (especially in the field of health care) and is still running today. Also, training in the responsible conduct of research (RCR) has been adopted by the United States, and is still being applied. The domain of RCR training does not only include the ethical dimensions of research with human subjects, but every intricate dimension of responsible conduct in the planning, performance, analysis, and reporting of research. Difficulties here arisen from the small amounts of resources allocated; see also the Organization for Economic Cooperation and Development (OECD) Guidelines for Multinational Enterprises, on the ethical paragraphs.

Concerning the philosophical and epistemological aspect of the issues in ethics and robotics, one of the main problems that people who are interested in roboethics will have to handle is the persistent confusion – ontologically, but especially linguistically – between human and artificial intelligence, as well as between other fundamental concepts of perception, consciousness, self consciousness, emotions, and so on, as applied to humans and to machines.

It must be clarified that the contemporary roboethics is human ethics as applied to robotics, which is considered nonhuman. A strong base of human roboethics is needed in order to responsibly construct the foundations of the final question, which nobody can yet answer: can robots ever become *human*?

This triaging choice, far from rendering the problem simple, renders it technically manageable and fertile of solutions useful to robotics and to society.

At the same time, the need for serious and thorough work into the concepts of intelligence, knowledge, conscience, autonomy, freedom, free will etc. is highlighted. Indeed, the heterogeneous composition of specialists often leads to incessant discussions about the meaning of words, rather than on the content of the myriad, often pressing, issues that need to be faced.

This work is in fact one of the philosophies of robotics, aiming to better define the scientific paradigm. It is important work, as robotics faces the ideal challenge of recreating life artificially and synthetically, which imposes a reopening of discussion and, in some cases, a need to redefine seemingly simple concepts, as well as the need to create new concepts. All this takes place in a multicultural context, which fuels vastly different philosophical backgrounds.

All of this leads to the necessity for the international robotics community to become the author of its own destiny, so as to face directly the task which needs defining, whilst collaborating with academics in the fields of philosophy of law, and generally with experts from the human sciences, to engage with the ethics and social aspects of their research and the applications of the former. Nor should they feel relegated to a mere techno-scientific role, delegating to others the task of reflecting and taking action on moral aspects. On the other hand, a closed-shop attitude would be damaging to the development of robotics, given the interdisciplinary nature of the much of the research undertaken in the field.

From this point of view, roboethics cannot fail to be beneficial to robotics, framing research in close connection with end users and society, and so avoiding many problems that other *sensitive* fields are now facing.

All this, and more, will be wishful thinking if engineering study curricula do not include subjects such as scientific philosophy, history of science, law, and the politics of science, as is already happening in some advanced polytechnics. Once again, we have to say that the deeper study of the history of science, for example, especially in the 19th and 20th centuries, cannot but aid a better understanding of that complex scientific galaxy which is robotics. Even a restricted knowledge of cybernetics and computer science, from Wiener, to von Neumann, to Weizenbaum, will immediately and directly demonstrate that these scientists immediately took care of the ethical and social aspects of their discoveries and realizations, which marked the beginning of the field of computers and robotics.

At the same time, it is necessary that those not involved in robotics keep up to date with the field's real and scientifically predictable developments, in order to base discussions on data supported by technical and scientific reality, and not on appearances or emotions generated by science fiction. In particular, apart from this handbook, one must look to serious magazines published by recognized scientific associations, and not rely on headlines about ambiguous and scandalizing creations that do not really exist.

Ethics is a 1000-year-old human science with an impressive literature. Its application to the field of science technology is no doubt more recent, even though precedents such as the Hippocratic oath suggest an extremely ancient origin. Research on robotics is throwing light on manifold issues across science and the humanities. No wonder it will also open new and unexpected field of studies and application in ethics.

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