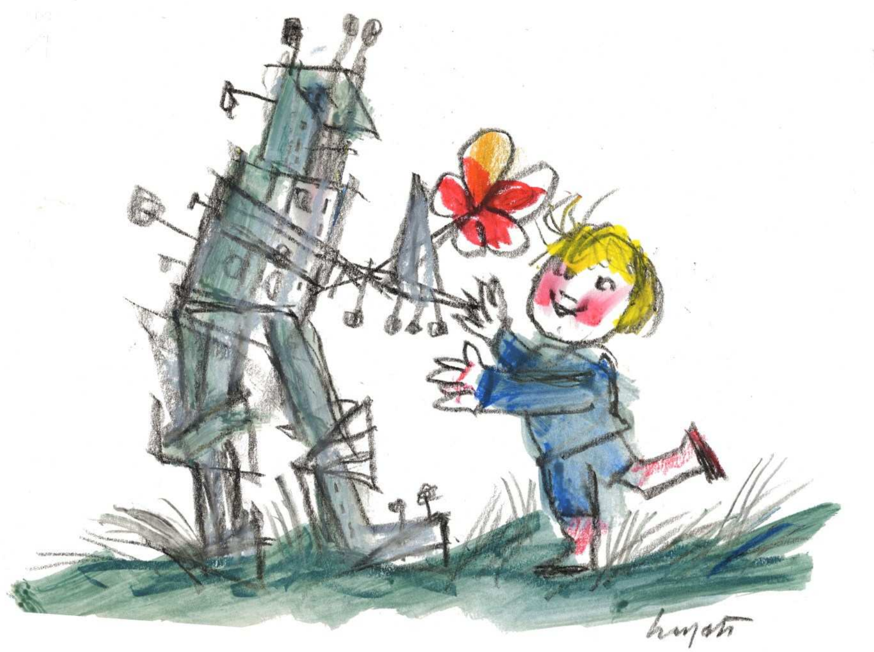
EURON Roboethics Atelier
Genoa, 27th of February – 3rd of March, 2006



EURON

Roboethics Roadmap

Scuola di Robotica (Project co-ordinator)
Dr. Gianmarco Veruggio

SUMMARY

1. INTRODUCTION

1.1. Ethics & Robotics

The importance and urgency of Roboethics 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 ethics and their research's applications because of pressure caused by dramatic and troubling events, or because of the concern of the general public. In many countries, public opinion, shocked by some of these effects, urged to either halt the whole research/applications, or to strictly control them.

Robotics is rapidly becoming one of the leading fields of science and technology: we can forecast that in the XXI century humanity will coexist with the first alien intelligence we have ever come into contact with - robots. It will be an event rich in ethical, social and economic problems. The public is already asking questions such as: "Could a robot do "good" and "evil"? "Could robots be dangerous for humankind?".

Like Nuclear Physics, Chemistry or Bioengineering, in a few years, Robotics could also be placed under scrutiny from an ethical standpoint by the public and Public Institutions (Governments, Ethics Committees, Supranational Institutions).

For all these reasons, scientists from the European robotics community, have alerted the need for the discussion of the framework of ethics that inspire the design, manufacturing and use of robots.

1.2. EURON (European Robotics Research Network)

EURON aims to promote excellence in robotics by creating resources and exchanging the knowledge we already have, and by looking to the future.

The means to achieve this objective are fivefold:

1. Research Coordination.
2. Joint Programme of Research (prospective research projects, topical research studies and **research ateliers)**.
3. Education & Training.
4. Industrial Links.
5. Dissemination.

1.3. EURON Robotics Research Roadmap

One major product of EURON is a robotics research roadmap designed to clarify opportunities for developing and employing advanced robot technology over the next 20 years. The document provides a comprehensive review of state of the art robotics and identifies the major obstacles to progress.

The main goals of the roadmapping activity are to identify the current driving forces, objectives, bottlenecks and key challenges for robotics research, so as to develop a focus and a draft timetable for robotics research in the next 20 years.

The Roboethics Atelier and the present Roboethics Roadmap should be included into this framework.

1.4. The Roboethics Atelier

In 2005, EURON funded the Project *Euron Roboethics Atelier*, with the aim of drawing the first Roboethics Roadmap.

Once the profile of the Euron Roadmap project had been discussed and its frame identified, the selection of participants started. This was done on the basis of:

- Their participation in previous activities on Techno/Roboethics;
- Their cross-cultural attitude,
- Their interest in applied ethics.

The last step in the process involved a series of discussions via e-mail which led to the definition of the Programme. Participants were asked to prepare a major contribution on their area of expertise, and on a few more on topics they were interested to discuss, even outside their realm of expertise. The organizers promoted the cross-cultural and transdisciplinary contributions.

In the frame of the Atelier, the parallel Ethicbots Project (in Science&Society Action Plan) was presented; and the Chairs of the IEEE Technical Committee on Roboethics met during the sessions.

1.5. The Roboethics Roadmap

The ultimate purpose of the Euron Roboethics Atelier, and of the Roboethics Roadmap is to provide a systematic assessment of the ethical issues involved in the Robotics R&D; to increase the understanding of the problems at stake, and to promote further study and transdisciplinary research.

The Roboethics Roadmap outlines the multiple pathways for research and exploration in the field and indicates how they might be developed. The roadmap embodies the contributions of more than 50 scientists and technologists, in many fields of investigations from sciences and humanities.

This study will hopefully be a useful aid in view of cultural, religious and ethical differences.

This Roboethics Roadmap should be considered the number 1 release, a preliminary and non exhaustive taxonomy of sensitive problems in the field.

Let's see firstly what the Roboethics Roadmap *cannot be*.

- It is not a *Survey*, nor a *State-of-the-Art* of the disciplines involved. This Roadmap does not aim to offer an exhaustive picture of the State-of-the-Art in Robotics, nor a guideline of ethics in science and technology. The reason is that:
    - Robotics is a new science still in the defining stage. It is in its blossoming phase, taking different roads according to the dominant field of science undertaken (field Robotics, Humanoids, Biorobotics, and so on). Almost every day we are confronted with new developments, fields of applications and synergies with other sectors.
    - Public and private professional associations and networks such as IFR-International Federation of Robotics, IEEE Robotics and Automation Society, EUROP - European Robotics Platform, Star Publishing House, have undertaken projects to map the State-of-the-Art in Robotics.
- It is not a list of *Questions & Answers*. Actually, there are no easy answers, and the complex fields require careful consideration.
- It cannot be a *Declaration of Principles*. The Euron Roboethics Atelier, and the sideline

discussion undertaken, cannot be regarded as the institutional committee of scientists and experts entitled to draw a Declaration of Principles on Roboethics.

This Roadmap has a defined scope and a target.

1.5.1. Scope: Near Future Urgency

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 a decade, 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 inherent in the possible emergence of human functions in the robot: like consciousness, free will, self-consciousness, sense of dignity, emotions, and so on. Consequently, this is why we have not examined problems –debated in literature – like the need not to consider robot as our slaves, or the need to guarantee them the same respect, rights and dignity we owe to human workers.

1.5.2. Target: Human Centred Ethics

Likewise, and for the same reasons, the target of this Roadmap 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, and about the chance that in the future robots might be moral entities like – if not more than– human beings, we have chosen, in this 1.0 release of the Roboethics Roadmap, to examine the ethical issues of the human beings involved in the design, manufacturing, and use of the robots.

We have felt that problems like those connected to 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 urging 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.

1.5.3. Methodology: Open Work

The Roboethics Roadmap is an *Open Work*, a *Directory of Topics & Issues*, susceptible to further development and improvement which will be defined by events in our technoscientific-ethical future. We are convinced that the different components of society working in Robotics, and the stakeholders in Robotics should intervene in the process of building a Roboethics Roadmap, in a grassroots science experimental case:

- The Parliaments
- Academic institutions
- Research Labs
- Public ethics committees
- Professional Orders
- Industry
- Educational systems
- The mass-media

1.6. Pre-history

Technoethical/Roboethical issues were introduced in previous robotics events and occasions:

- 2001, the Italy-Japan 2001 Workshop "Humanoids: a Techno-Ontological approach" held in Tokyo;
- 2002, the Opening Workshop at ICRA 2002, in a thesis by Josè Maria Galvàn entitled "Techno-Ethics", published in the December 2003 RAM Issue (José M. GALVAN, On Technoethics, in IEEE-RAS Magazine (2003/4) 58-63);
- 2004, *First International Symposium on Roboethics* , Sanremo, Italy, organized by School of Robotics, where, the word *Roboethics* was officially used for the first time;
- 2004, IEEE-RAS established a Technical Committee on Roboethics:
- 2004, *Fukuoka World Robot Declaration*, issued on February 25, in Fukuoka, Japan:

> *"Confident of the future development of robot technology and of the numerous contributions that robots will make to Humankind, this World Robot Declaration is Expectations for next-generation robots: a) next-generation robots will be partners that coexist with human beings; b) next-generation robots will assist human beings both physically and psychologically; c) next-generation robots will contribute to the realization of a safe and peaceful society"*.

- 2005, ICRA (International Conference on Robotics and Automation), Barcelona: the IEEE RAS TC on Roboethics organized a Workshop on Roboethics.
- 2006, BioRob2006 (The first IEEE / RAS-EMBS International Conference on Biomedical Robotics and Biomechatronics), Pisa, Italy: Minisymposium on Roboethics

1.7. Documentary and background material

Documentary material on Robotics and Ethics was provided by:

Almost a week of discussions during the Euron Roboethics Atelier, Genoa and discussions and papers from:

- First International Symposium on Roboethics, Sanremo, 2004
- Fukuoka Fair, Japan, 2004
- IEEE Workshop, ICRA 2005
- Robocasa Conference, Japan 2005
- Biorob, Pisa, 2006

We also collected documents from:

- robotics researches
- applications cases
- Robotics labs
- witness from scientists
- documents and discussions with scientists and experts in Humanities via Web.

2. ETHIC AND ETHICS

According to the *Oxford Dictionary of Philosophy*, Ethics is “the branch of philosophy concerned with the evaluation of human conduct” (Blackburn, S (1996). *Oxford Dictionary of Philosophy*, Oxford University Press).

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.” (Paul Newall, 2005, http://www.galilean-library.org/int11.html)
In short “*Morality*” is the subject of a science called “*Ethics*”. (Although *Morality* may also refer to a code of conduct: http://plato.stanford.edu/entries/morality-definition/).

The definition of *good* and *bad* differ according to ages, cultures and societies – on the basis of religious beliefs, moral values, professional duties, social obligations and prohibitions.

- ***Meta-Ethics*** Meta-ethics, the study of what in essence ethical values are, how such values are obtained and how moral goods are achieved, in any context. It analyzes the language of morals, or the linguistic properties of moral arguments. Reasoning about morals is linguistic activity and governed by the rules of proper use of language. If moral words have special linguistic properties (for example, if “ought” implies universal applicability), such properties will guide our moral arguments and influence the results of rational discourse.
- ***Descriptive Ethics*** analyses the ethical standards or principles of a specific group or tradition.
- ***Normative Ethics*** is the development of theories that systematically denote right and wrong actions.
- ***Applied Ethics*** is the application of a particular set of circumstances and practices to the given theory of ethics adopted by the group.

In scientific circles, *Secular Humanism* - a non theistically ethical philosophy based upon naturalism, rationalism and free thought - gained great importance and influence.
Different world cultures, religions and societies have different concept of ethics, and have different ideas, definitions and applications of the concepts of life, human dignity, freedom, consciousness, privacy, and so on.

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. However, we cannot underestimate the impact of society’s opinions on *Science&Society* issues, and on the trend of the advancement of science and technology; nor forget that in some cases civil society intervened to stop or limit the field of science that they considered to be dangerous and problematic.
However, *Ethics in the digital world* needs new approaches, beyond the classical moral theories,

opening new and unresolved moral problems in dealing with:

- new disciplines;
- new technological objects which are not only tools for work but *agents*, companions, avatars (Floridi).

A part *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 behaviour. 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.[5]) Nor is the idea that we are, now, implicitly committed to a contract of the 'I won't hit you if you don't 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 goals achieved.

2.1. Ethical Issues

Here below are some of the ethical issues connected to the Roboethics Roadmap which can differ, in their definition and application, according to cultures, religions and societies:

- Concepts of Immanentism/Transcendentalism;
- What is human?; post-human? Cyborg?
- Human life/artificial life;
- Human intelligence/artificial intelligence;
- Privacy vs. traceability of actions;
- Integrity of the person/perception of human being;
- Diversity (Gender, Ethnicity, Minorities)
- Freedom;
- Human enhancement (physical, cognitive; through gene therapy, ICT, silicon implants, robotics, nanotechnology);
- What is science/knowledge?
- Animal welfare.

2.2. Principles to be followed in Roboethics:

- Human Dignity and Human Rights
- Equality, Justice and Equity
- Benefit and Harm
- Respect for Cultural Diversity and Pluralism
- Non-Discrimination and Non-Stigmatization

- Autonomy and Individual Responsibility
- Informed Consent
- Privacy
- Confidentiality
- Solidarity and Cooperation
- Social Responsibility
- Sharing of Benefits
- Responsibility towards the Biosphere.

2.3. *Ethical Issues in an ICT society*

Roboethics shares many “sensitive areas” with Computer Ethics and Information Ethics. But, before that, we have to take into account the global ethical problems derived from the Second and Third Industrial Revolutions, in the field of the relationship between Humans and Machines:

- Dual-use technology (every technology can be used and misused);
- Anthropomorphization of the Machines;
- Humanisation 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;
- Effects of technology on the global distribution of wealth and power;
- Environmental impact of technology.

From the Computer and Information Ethics we borrow the known Codes of Ethics called *PAPA*, acronym of: privacy, accuracy, intellectual property and access.

- *Privacy*: What information about one's self or one's 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?

By *Engineering Ethics* are meant the Codes of Ethics bearing on the professional responsibilities of engineers, guiding to a responsible conduct in research and practice. In this context, *Security* and *Reliability* are the most important ethical codes of conduct. Furthermore:

- 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.

(*American Council of Engineering Companies Ethical Guidelines*)

Questions raised on the range of application of sensitive technologies, and on the uncertainty of performance of these are raised in connection to neuro-robotics:

- 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 vs. enhancement?
- This issue is especially notable regarding the problem of *augmentation*: In some cases a 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 technology itself should be considered unacceptable even though it has 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.

(Wagner, J.J, David M. Cannon, D.M., Van der Loos).

2.4. The precautionary principle

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

Professional 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.
http://ec.europa.eu/comm/dgs/health_consumer/library/pub/pub07_en.pdf
From the precautionary principle derive some other rules such as

- non-instrumentalisation
- non-discrimination
- informed consent and equity

- sense of reciprocity
- data protection

The aim of this roadmap is to open a debate on the ethical basis which should inspire the design and development of robots, to avoid the need to become conscious of the ethical basis only under the pressure of grievous events. We agree that "precaution should not produce paralysis of science and technology" (G. Tamburrini).

3. ETHICS IN SCIENCE AND TECHNOLOGY

"What is science? Not the collection of facts but the establishment, through open debate, of new principles that command wide acceptance The process of incorporating ethical concerns and recommendations in daily application." (John Polanyi, Nobel Laureate)

The issue of scientific responsibility towards society has most often arisen after the misuse of scientific discoveries.
Concerns about science research and application grew after the Hiroshima and Nagasaki bombings, and more recently as a result of the emergence of applications of biotechnologies to human reproduction.
Concerned scientists; stakeholders; NGO's warning about the future of our planet; parents warning about the invasion of technology in children's rooms, have proposed to scientists, manufacturers, distributors, and advertising agencies the adoption of ethical conducts.

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 be incorporated in the current application of research and development?

Here below the main social and institutionalized forms of codes of conducts.

3.1. Oath & pledge

The Hippocratic Oath or Pledges are recurrent examples for other initiatives to develop and implement codes of conduct for scientists in general, and scientists in specific areas in particular.
Here below a case of a Hippocratic Oath for Scientists.
Sir Joseph Rotblat, one of the founders of the Pugwash movement, received the 1995 Nobel Peace Prize for his world-changing work with this organization. In response to the Nobel Peace Prize and as an acknowledgment to Professor Rotblat's commitment to young people, Student Pugwash USA developed their pledge, a "Hippocratic Oath" for scientists. This pledge has already been signed by thousands of students from many countries.

3.2. Code & guideline

A collection of laws, or regulations; a written text that offers guidelines – e.g., 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 good in the widest sense.

Here below some quotes from one of the most known manuals for scientists and researchers, developed by OECD (Organisation for Economic Co-operation and Development):

> *Art. 3.4 Researchers must not compromise the overriding principles of non-malfeasance and beneficence, legal obligations and any pre-existing rights in the conduct of research.*
>
> *Art. 3.5 Researchers must weigh up the potentially conflicting risks and benefits of a particular piece of research, for instance the potential conflict between human and animal welfare.*
>
> *Art. 3.7 Researchers should consider the ethical implications of the research and the physiological, psychological, social, political, religious, environmental, cultural and economic consequences of the work for the participants. Researchers should be sensitive to the possibility of blasphemy or giving offence to followers of faiths or beliefs arising from a piece of work.*
>
> *Art. 3.8 Where the researcher is not fully competent or sufficiently informed to make a fair judgement about the conflicting needs and interests of direct and indirect participants, it is essential that specialist advice is sought.*
>
> *a) Informed consent*
> *b) Confidentiality and data protection*
> *c) Animal rights*
> *d) Research undertaken in public places*
> *e) Academic Integrity*
> *f) Contractual responsibilities*

The OECD manual for the measurement of resources devoted to research and experimental development, the "Frascati Manual" (1994), was written by and for the national experts in OECD countries who collect and issue national R&D data and who submit responses to OECD international R&D surveys, aided by the staff of the OECD Economic Analysis and Statistics Division.

3.3. Appeal

An appeal is an earnest request for support: a petition, entreaty, or plea.
For example, the Appeal to GDCh (Gesellschaft Deutscher Chemiker) members to endorse a resolution against discrimination, racism and xenophobia (2000).

3.4. Recommendation

A recommendation serves to induce acceptance or favour. A recommendation is a prescription only in the weak sense of offering advice: a normative suggestion that is neither legally nor morally binding. It can, however, urge advice quite forcefully. E. g. Recommendation N. (2000)8 of the Council of Europe’s Committee of Ministers to member states on the research mission of universities.

3.5. Manifesto

A manifesto is a public declaration of intentions, opinions, objectives or motives, often issued by a government, sovereign or organization.

For example, the Russell-Einstein Manifesto of 1955 is a public declaration against war and the further development of weapons of mass destruction:

> *"In view of the fact that in any future world war nuclear weapons will certainly be employed, and that such weapons threaten the continued existence of mankind, we urge the governments of the world to realize, and to acknowledge publicly, that their purpose cannot be furthered by a world war, and we urge them, consequently, to find peaceful means for the settlement of all matters of dispute between them."*

3.6. Statement & declaration

Basically, a statement or a declaration is a communication in speech or writing setting forth facts, particulars, etc. As such, it can be either weakly or strongly prescriptive, morally or legally binding. To illustrate: (a) An international declaration, such as the UN declarations, is binding in international law (the status of which is, however, controversial within jurisprudence) once the member countries have accepted it. A declaration is legally binding nationally if it is formally ratified and transformed into the national legislation.
(b) An international statement, such as the 'Federation of European Laboratory Animal Associations (FELASA) non-human primate statement', sets forth norms that are morally binding for the members of FELASA unconnected to legislation.

3.7. Resolution

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

3.8. Convention

A convention is a form of agreement, or a contract. It can also mean a practice established by general consent. An international convention is an agreement between different states concerning a specific matter, such as postal service, copyright, etc. Such a convention is, for example, the European Convention on Human Rights and Biomedicine (Oviedo 1997). If a convention is ratified it becomes binding for the individual states.

3.9. Charter

Ancient term which remains ambiguous and complex still today, but its basic meaning can perhaps be described as a legal act or document defining the formal organisation of a corporate body or a constitution conceding special rights and privileges. An example is the Charter of the United Nations. The charters have a legal character and are connected, in principle, to sanctions when not properly executed.

3.10. Law

Principles established by a government applicable to a people and enforced by judicial decision.

(Source: *Codes of Conduct*, *Standards for Ethics in Research,* Dr. Kathinka Evers, European

Commission, Directorate-General for Research, Directorate C – Science and Society, Unit C.3, Ethics and Science)

3.11. Conditions for Implementation

Any regulation or code of conduct shall be subject to Conditions for Implementation. Regulations cannot be implemented without at least some of those conditions, which should favour the application of the rules and which are:
Individual and environmental conditions:

- Decision-Making: the empowered position and freedom to identify and choose alternatives based on the values and preferences defined and accepted;
- Honesty and Integrity
- Transparency of processes

Institutional conditions:

- 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 ocountries and comparisons of professional ethics around the world

3.12. 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'.
See, for this: the interpretation of the principles in the Universal Declaration on Bioethics and Human Rights (United Nations Educational, Scientific and Cultural Organization, *Universal Declaration on Bioethics and Human Rights*, 19 October 2005).

4. UNIVERSALLY ADOPTED ETHICAL PRINCIPLES

In roadmapping Roboethics, we refer to the General Ethical Principles adopted by most nations, Cultures and People of the World.

International Charts and Declarations.

4.1. United Nations

- United Nations Universal Declaration of Human Rights (10 December 1948),
- International United Nations Covenants on Economic, Social and Cultural Rights and on Civil and Political Rights of 16 December 1966,
- United Nations Convention on the Prevention and Punishment of the Crime of Genocide of 9 December 1948,
- International United Nations Convention on the Elimination of All Forms of Racial Discrimination of 21 December 1965,

- United Nations Declaration on the Rights of Mentally Retarded Persons of 20 December 1971,
- United Nations Declaration on the Rights of Disabled Persons of 9 December 1975,
- United Nations Convention on the Elimination of All Forms of Discrimination Against Women of 18 December 1979,
- United Nations Convention on the Rights of the Child of 20 November 1989,
- United Nations Standard Rules on the Equalization of Opportunities for Persons with Disabilities of 20 December 1993,
- Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction of 16 December 1971

4.2. Unesco

- Unesco Convention against Discrimination in Education of 14 December 1960,
- Unesco Declaration of the Principles of International Cultural Co-operation of 4 November 1966,
- Unesco Recommendation on the Status of Scientific Researchers of 20 November 1974,
- Unesco Declaration on Race and Racial Prejudice of 27 November 1978,
- Universal Declaration on Bioethics and Huma http://www.catacconference.org/n Rights (19 October 2005)
- Unesco: Ethics and the Responsibility of Science
- Unesco: Declaration on Science and the use of scientific knowledge (1 July 1999) [FR]
- Unesco: Universal Declaration on the Human Genome and Human Rights, (11 November 1997)
- Unesco: Cartagena Protocol on Biosafety (Montreal, 2000)
- Unesco: Convention on Biological Diversity (5 June 1992)

4.3. Ilo - International Labor Organization

- ILO Convention (No. 111) concerning Discrimination in Respect of Employment and Occupation of 25 June 1958.
- ILO Convention (No. 169) concerning Indigenous and Tribal Peoples in Independent Countries of 27 June 1989.
- 22 C/Resolution 13.1, 23 C/Resolution 13.1, 24 C/Resolution 13.1, 25 C/Resolutions 5.2 and 7.3, 27 C/Resolution 5.15 and 28 C/Resolutions 0.12, 2.1 and 2.2, urging UNESCO to promote and develop ethical studies, and the actions arising out of them, on the consequences of scientific and technological progress in the fields of biology and genetics, within the framework of respect for human rights and fundamental freedoms.

4.4. The Nuremberg Code

From Trials of War Criminals before the Nuremberg Military Tribunals under Control Council Law No. 10. Nuremberg, October 1946–April 1949. Washington, D.C.: U.S. G.P.O, 1949–1953

4.5. World Medical Association

(WMA) Declaration of Helsinki, Ethical Principles for Medical Research Involving Human Subjects, adopted by the 18th WMA General Assembly, Helsinki, Finland, June 1964, and amendments.

4.6. World Summit on the Information Society

Declaration of Principles , Geneva, 12 December 2003.
http://www.itu.int/wsis/docs/geneva/official/dop.html

4.7. European Union

Charter of Fundamental Rights of the European Union (2000/C 364/01) signed and proclaimed by the Presidents of the European Parliament, the Council and the Commission at the European Council meeting in Nice on 7 December 2000, esp.:

- Article 3: Right to the integrity of the person
- Article 13: Freedom of the arts and sciences
- Article 8: Protection of personal data
- Article 10: Freedom of thought, conscience and religion

The Charter of European Fundamental Rights has established these general ethical principles (and more) as fundamental rights in Europe. The extent to which these principles have become part of everyday life varies between the Member States. How they apply would be more specifically expressed within national legislation.

- Directive 95/46 on the protection of personal data
- Directive 2001/83/EC on medicinal products for human use
- Directive 98/44/EC on the legal protection of biotechnological inventions
- Directive 86/609/EEC on the protection of animals used fore experimental and other scientific purposes
- Protocol on Protection and welfare of animals (Protocol to the Amsterdam Treaty)
- Regulation (EC) No 1830/2003 on traceability and labelling of genetically modified organisms and the traceability of food and feed products produced from genetically modified organisms and amending Directive 2001/18/EC
- Council Decision 2002/835/EC adopting a specific programme for research, technological development and demonstration: ‘structuring the European Research Area’ (2002–2006)
- Directive 2001/20/Ec of the European Parliament And of The Council of 4 April 2001 on the approximation of the laws, regulations and administrative provisions of the Member States relating to the implementation of good clinical practice in the conduct of clinical trials on medicinal products for human use.
- Directive 2002/58/EC of the European Parliament and of the Council of 12 July 2002 concerning the processing of personal data and the protection of privacy in the electronic communications sector,
- Directive 95/46/EC of the European Parliament and of the Council of the European Union of 24 October 1995 on the protection of individuals with regard to the processing of personal data and on the free movement and on the free movement of such data

- Council Directive 90/385/EEC of 20 of June 1990 on the approximation of the laws of the Member States relating to active implantable medical devices;
- Council of Europe on Human Rights and Biomedicine, signed on 4 April 1997 in Oviedo,
- Convention for the Protection of Individuals with regard to the Automatic Processing of Personal Data of the Council of Europe of 1 January 1981
- Council of Europe: Convention for the protection of Human Rights and dignity of the human being with regard to the application of biology and medicine: Convention on Human Rights and Biomedicine (4 April 1997)
- Council of Europe: Additional Protocol to the Convention for the Protection of Human Rights and Dignity of the Human Being with regard to the Application of Biology and Medicine, on the Prohibition of Cloning Human Beings (12 January 1998)
- Council of Europe: Additional Protocol to the Convention on Human Rights and Biomedicine concerning Transplantation of Organs and Tissues of Human Origin (24 January 2001)

4.8. Charter Of Fundamental Rights of the European Union (2000)

Articles of interest:

- Human dignity
- Right to life
- Right to the integrity of the person
- Respect for private and family life
- Protection of personal data
- Freedom of the arts and sciences
- Freedom to choose an occupation and right to engage in work
- The rights of the child
- The rights of the elderly
- Integration of persons with disabilities
- Environmental protection
- Consumer protection

(http://www.europarl.europa.eu/charter/default_en.htm)

4.9. General rules regarding ethics in EU research activities

In the “Ethics - The Ethical Review Procedure” section of Science and Society Action Plan, it is said (http://ec.europa.eu/research/science-society/page_en.cfm?id=3200):

“Article 3 of the FP6 states that "All the research activities carried out under the Sixth Framework Programme must be carried out in compliance with fundamental ethical principles. In order to implement this article the European Commission has introduced an ethical review for proposals raising sensitive ethical issues into the evaluation process (…)

All proposals for research submitted to the European Commission for funding must include a section describing the ethical issues raised by the project regarding its methodology, the objectives and the possible implications of the results and the way they will be tackled (…) principles reflected in the Charter of fundamental rights of the European Union such as protection

of human dignity and human life, protection of personal data and privacy as well as the environment (…)
The objective of this additional assessment is to make sure that the European Union is not supporting research which might violate fundamental ethical principles.
Integrated Projects and Networks of Excellence in the priority areas of research are encouraged to take on board specific research and stakeholder groups to study the ethical impact of the research undertaken".
Possible ethical implications of the research results such as

- protection of dignity
- autonomy, integrity and privacy of persons,
- biodiversity,
- protection of the environment,
- sustainability
- animal welfare

See also:

- The European Group on Ethics
- The Forum of National Ethics Councils (NEC Forum), an informal, independent platform for exchange of information, experience and best practices on issues of common interest in the field of ethics and science.

5. Intercultural understanding and dialogue

The international scientific, juridical, economical, and regulatory community, often grouped under Unesco's Committees, has in many occasions proposed a harmonisation of world ethical principles, especially in those cases when those principles are concerning the application of science and technology to 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, December 2003, COMEST organized an international conference on the issue of a *Universal Ethical Oath for Scientists.*

There are many Centre for Applied Ethics and centres dealing with related issues in Europe, United States, Canada, Latin America, India and Asia.

5.1. International Center for Information Ethics

The ICIE was created in 1999 by Rafael Capurro (Hochschule der Medien - Stuttgart University of Applied Sciences, Germany). It started as a small group of friends and colleagues but developed soon into an international and intercultural platform with by now more than 180 members from all over the world. Since 2004 ICIE publishes the International Review of Information Ethics (IRIE). (http://icie.zkm.de/)

5.2. International Society for Ethics and Information Technology

INSEIT was created at a Computer Ethics, Philosophical Inquiry conference at Dartmouth College in 2000. (http://csethics.uis.edu/inseit/)

5.3. Cultural Attitude Towards Technology and Communication Conference (CATaC)

The biennial CATaC conference series continues to provide an international forum for the presentation and discussion of current research on how diverse cultural attitudes shape the implementation and use of information and communication technologies (ICTs). The conference series brings together scholars from around the globe who provide diverse perspectives, both in terms of the specific culture(s) they highlight in their presentations and discussions, and in terms of the discipline(s) through which they approach the conference theme. (http://www.catacconference.org/)

5.4. The Pugwash Conference on Science and World Affairs

The Pugwash Conferences was founded following the Manifesto issued in 1955 by Bertrand Russell and Albert Einstein -- and signed also by Max Born, Percy Bridgman, Leopold Infeld, Frederic Joliot-Curie, Herman Muller, Linus Pauling, Cecil Powell, Joseph Rotblat, and Hideki Yukawa -- which called upon scientists of all political persuasions to assemble to discuss the threat posed to civilization by the advent of thermonuclear weapons. (http://www.pugwash.org/)

5.5. Computer Professional for Social Responsibility (CPSR)

CPSR is a global organization promoting the responsible use of computer technology. Founded in 1981, CPSR educates policymakers and the public on a wide range of issues. CPSR has incubated numerous projects such as Privaterra, the Public Sphere Project, EPIC (the Electronic Privacy Information Center), the 21st Century Project, the Civil Society Project, and the CFP (Computers, Freedom & Privacy) Conference. Originally founded by U.S. computer scientists, CPSR now has members in over 30 countries on six continents. (http://www.cpsr.org/about/)
(http://www.ucsusa.org/)

5.6. Makkula Center

The Makkula Center for Applied Ethics at Santa Clara University, USA, is the sea for research and dialogue on ethical issues in critical areas of American life. The center works with faculty, staff, students, community leaders, and the public to address ethical issues more effectively in teaching, research, and action. The center's focus areas are business, health care and biotechnology, character education, government, global leadership, technology, and emerging issues in ethics. Articles, cases, briefings, and dialogue in all fields of applied ethics are available on this site. (http://www.scu.edu/ethics/)

5.7. The Centre for Responsible Nanotechnology

The Centre for Responsible Nanotechnology is a non-profit research and advocacy organization concerned with the major societal and environmental implications of advanced nanotechnology. CRN promotes public awareness and education, and the crafting and implementation of effective policy to maximize benefits and reduce dangers.

Their mission is to “engage individuals and groups to better understand the implications of molecular manufacturing and to focus on the real risks and benefits of the technology. Their goal is the creation and implementation of wise, comprehensive, and balanced plans for global management of this transformative technology". (http://www.crnano.org/)

5.8. Union of Concerned Scientists

UCS is an independent non-profit alliance of more than 100,000 concerned citizens and scientists. Their mission is "rigorous scientific analysis with innovative thinking and committed citizen advocacy to build a cleaner, healthier environment and a safer world".

5.9. The International Institute of Humanitarian Law

As an independent organisation, the Institute especially encourages dialogue among governments, organisations and institutions concerned with humanitarian issues, as well as with individual experts. Since its creation, the Institute has dealt with a broad range of subjects regarding humanitarian law and action. It has also shown how the law of human rights, humanitarian law and refugee law are all interrelated and interdependent. (www.iihl.org)

5.10. The World Transhumanist Association

The World Transhumanist Association is an international non-profit membership organization which "advocates the ethical use of technology to expand human capacities". They "support the development of and access to new technologies that enable everyone to enjoy better minds, better bodies and better lives". In other words, they want people to be better than well. (http://www.transhumanism.org)

For additional consultation:
http://icie.zkm.de/institutions

6. ROBOTICS AND ETHICS

Is Robotics a new science, or is a branch or a field of application of Engineering?
Actually Robotics is a discipline born from:

- Mechanics
- Physics/Mathematics
- Automation and Control
- Electronics
- Computer Science
- Cybernetics
- Artificial Intelligence

This shows that Robotics is a unique combination of many scientific disciplines, whose fields of applications are broadening more and more, according to the scientific and technological achievements.

6.1. Specificity of Robotics

It is the first time in history that humanity is approaching the threshold of replicating an intelligent and autonomous entity. This compels the scientific community to examine closely the

very concept of intelligence – in humans, animals, and of the machines – from a cybernetic standpoint.
In fact, complex concepts like autonomy, learning, consciousness, evaluation, free will, decision making, freedom, emotions, and many others shall be analysed, taking into account that the same concept shall not have, in humans, animals, and machines, the same semantic meaning.
From this standpoint, it can be seen as natural and necessary that Robotics draws on several other disciplines:

- Logic/Linguistics
- Neuroscience/Psychology
- Biology/Physiology
- Philosophy/Literature
- Natural History/Anthropology
- Art/Design

Robotics *de facto* unifies the so called *two cultures,* Science and Humanities.
The effort to design Roboethics should make the unity of these two cultures a primary assumption. This means that experts shall view Robotics as a whole - in spite of the current early stage which recalls a *melting pot* – so they can achieve the *vision* of the Robotics' future.

6.2. About Roboethics

In 1942, novelist Isaac Asimov formulated, in the novel *Runaround*, the Three Laws of Robotics:

1. *A robot may not injure a human being, or through inaction, allow a human being to come to harm.*
2. *A robot must obey the orders given it by human beings except where such orders would conflict with the First 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 Asimov added the Fourth Law (known as Law Zero):

4. *No robot may harm humanity or, through inaction, allow humanity to come to harm.*

The theme of the relationship between humankind and *autonomous* machines – or, automata - appeared early in world literature, developed firstly through legends and myths, more recently by scientific and moral essays.

The topic of the rebellions of automata recurs in the classic European literature, as well as the misuse or the evil use of the product of ingenuity. It is not so in all the world cultures: for instance, the mythology of the Japanese cultures does not include such paradigm. On the contrary, machines (and, in general, human products) are always beneficial and friendly to humanity.

These cultural differences in attitudes towards machines are a subject the Roboethics Roadmap should take into account and analyse.
Questions:

- Although farsighted and forewarning, could Asimov's three Laws become really the *Ethics of Robots*?

- Is Roboethics the ethics of robots or the ethics of robotic scientists?
- How far can we go in embodying ethics in a robot? And, which kind of "ethics" is the correct one for Robotics?
- How contradictory is, on one hand, the need to implement Roboethics in robots, and, on the other, the development of robot autonomy?
- Is it right that robots can exhibit a "personality"?
- Is it right that robots can express "emotion"?

6.3. What is a Robot?

Robotics scientists, researchers, and the general public have about robots different evaluations, which should taken into account in the Roboethics Roadmap.

6.3.1. Robots are nothing 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 they be provided with consciousness, free will, or with the level of autonomy superior to that embodied by the designer. In this frame, Roboethics can be compared to an Engineering Applied Ethics.

6.3.2. Robots have ethical dimensions

In this view, an ethical dimension is intrinsic within robots. 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, like language and computers, but even more, humanoid robots are symbolic devices designed by humanity to extend, enhance, and improve our innate powers, and to act with charity and god intentions. *(J. M. Galvan)*

6.3.3. Robots as moral agents

Artificial agents, particularly but not only those in Cyberspace, 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 (not necessarily exhibiting free will, mental states or responsibility, but as entities that can perform actions, again for good or evil).
This complements the more traditional approach, common at least since Montaigne and Descartes, which considers whether or not (artificial) agents have mental states, feelings, emotions and so on. By focusing directly on 'mind-less morality' we are able to avoid that question and also many of the concerns of Artificial Intelligence. *(L. Floridi)*

6.3.4. Robots, evolution of a new specie

According to this point of view, not only will our robotics machines have autonomy and consciences, but 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. *(J. Storrs Hall)*

6.4. Main positions on Roboethics

Since the First International Symposium on Roboethics, three main ethical positions emerged from the robotics community *(D. Cerqui)*:

6.4.1. Not interested in ethics.

This is the attitude of those who consider that their actions are strictly technical, and do not think they have a social or a moral responsibility in their work.

6.4.2. Interested in short-term ethical questions.

This is the attitude of those who express their ethical concern in terms of "good" or "bad," and who refer to some cultural values and social conventions. This attitude includes respecting and helping humans in diverse areas, such as implementing laws or in helping elderly people.

6.4.3. Interested in long-term ethical concerns.

This is the attitude of those who express their ethical concern in terms of global, long-term questions: for instance, the "Digital divide" between South and North; or young and elderly. They are aware of the gap between industrialized and poor countries, and wonder whether the former should not change their way of developing robotics in order to be more useful to the latter.

6.5. About the Name

The name Roboethics *(coined in 2002 by G. Veruggio)* was officially proposed during the First International Symposium of Roboethics (Sanremo, Jan/Feb. 2004), and rapidly showed its potential, for several reasons:

- Naming *things* - according to the Principles of Composition -Gives them reality (*Nomina sunt consequentia rerum)*;
- People more readily pay attention to a concept which is linked to "the inherent nature of the material";
- It recalls the well-known word *Bioethics*;

- Since then the word Roboethics has been widely used in and by:
- Official publications and Projects,
- Universities and Research Centres,
- Professional Associations (*see* IEEE-RAS Robotics and Automation Society, AAAI American Association for Artificial Intelligence, WHO World Health Organisation),
- Papers, publications,
- media
- the Internet.

6.6. Disciplines involved in Roboethics

The design of Roboethics will require the combined commitment of experts of several disciplines, who, working in transnational projects, committees, commissions, will have to adjust laws and regulations to the problems resulting from the scientific and technological achievements in Robotics.

In all likelihood, we will witness the birth of new *curricula studiorum* and specialities, necessary to manage a subject so complex, juts as it happened with Forensic Medicine.

In particular, we mention the following fields as the main ones to be involved in Roboethics:

- Robotics
- Computer Science
- Artificial Intelligence

- Philosophy
- Ethics
- Theology
- Biology/Physiology
- Cognitive Sciences
- Neurosciences
- Law
- Sociology
- Psychology
- Industrial Design

7. ROBOETHICS TAXONOMY

In the period of a year, the Euron Roboethics Atelier will have carried out a *tour d'horizon* of the field in Robotics: an overview of the state of the art in Robotics, and of the main ethical issues, driven by the most recent technoscientific developments, which can only just be glimpsed.

A taxonomy of Robotics is not a simple task, simply because the field is in a full bloom.

A classification of Robotics is a work in progress, done simultaneously with the development of the discipline itself.
Aware of the classifications produced by the main Robotics organizations, which differ from one another on the basis of the approach – technological/applicational -, we have preferred, in the case of the Roboethics Roadmap, to collect the many Robotics fields from a typological standpoint, according to shared homogeneity of the problems of interface towards the society.
Instead of an encyclopaedic approach, we have followed - with few modifications - the classification of *EURON Robotics Research Roadmap*.

For every field, we have tried to analyse the current situation rather than the imaginable. Thus, we have decided to give priority to issues in applied ethics rather than to theoretical generality.

It should be underscored that the present grid is not exhaustive; it is the number 1.0 release of the Roboethics Roadmap, subject to correction and improvement.
The following chapters consist of the classification of the main typologies of ethical problems in Robotics, as they emerged from the contribution of the Participants to the Atelier, and from a broad array of documentation.
It should also be noted that Robotics, unlike other sciences, has not yet been affected by practical ethical cases, nor has it had to deal with dramatic situations.

7.1. 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.

"Essentially, it is expected that a robot will provide assistance in housework, for aged people and for entertainment to keep up the amenity of life and human environment in the next century. A type of human robot, a Humanoid is expected, to work together with human partners in our living environment, and it will share the same working space and will experience the same thinking and behaviour patterns as a human being. The robot will integrate information from sensors and show coordinated actions which realize a high level of communication with a human without any special training using multimedia such as speech, facial expression and body movement" (*source*, Waseda Humanoid Robotics Institute)

7.1.1. Artificial Mind

We shall introduce here, in summary, the concept of intelligence. In this Roadmap, we limit ourselves to defining intelligence from an engineering point of view, that is, an operational intelligence – although we are aware of the fact that our terminology regarding robots' functions is often taken from the language used for human beings.

According to the *Computational Theory of the Mind*, (H. Putnam, 1961) the human mind is structured on a set of hierarchical representational abilities which allow humans to understand beliefs, goals, and desires of others, on the basis of an internal model, and within an intentionally directed framework.

Artificial Intelligence shall be able to lead the robot to fulfill the missions required by the end-users. To achieve this goal, in recent years scientists have been working on AI techniques in many fields. Among them:

a) Artificial vision;
b) Perception and analysis of the environment;
c) Natural Language Processing;
d) Human interaction;
e) Cognitive Systems;
f) Machine learning, behaviours;
g) Neural Networks;

From our point of view, one of the fundamental aspects of robots is their capability to learn: to learn the characteristics of the surrounding environment, that is, a) the physical environment, but also b) the living beings who inhabit it. This means that robots working in a given environment have to recognise human beings from other *objects*.

In addition to learning about the environment, robots have to learn about their own behaviour, through a self reflective process. They have to learn from experience, replicating somehow the natural processes of the evolution of intelligence in living beings (synthesis procedures, trial-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 incorporated into the control algorithm of the robots. Robotics intelligence is a learned intelligence, fed by the world's models uploaded by the designers. It is a self-developed intelligence, evolved through the experience robots have achieved and through the learned effects of their actions. Robotics intelligence comprises also the ability to evaluate, to attribute a judgement to the actions carried out.

All these processes embodied in 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 which is unpredictable for their human designers.

Basically, the increasing autonomy of the robots could give rise to unpredictable and non predictable behaviours.

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

7.1.2. Artificial Body

Humanoids are robots whose body structure resembles the human one. They answer to an old dream of humanity, and certainly do not spring only from rational, engineering or utilitarian motivations, but also from psycho-anthropological ones.
Humanoids are the expression of one of the demands of our European culture, that is that humankind were created some mechanical being in the shape of a human. In the Japanese culture, it is the demand to carefully replicate nature in all its forms.
It is a very difficult and demanding enterprise, a project of the level of the *Mission to the Moon*. But, precisely for its characteristic of being one of humanity's dreams, the investments are high and the speed of progress very quick.

It has been forecasted that that it will be possible, in certain situations, to confuse one with the other. Humanoids will assists 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/disabled 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.

In the frame of this Roadmap, there is no need to closely examine the technological aspects of humanoids (actuators, artificial muscles; robot path planning; visual aspect and the realization of emotion in humanoid robots; expressions of verbal and nonverbal information in robots; environment and human recognition of human faces; human-machine communication interface; and so on). Many of these technologies come from biorobotics; and many, born in the humanoids labs, are and will be applied to biorobotics.

7.1.3. Benefits

- Intelligent machines can assist humans to perform very difficult tasks, and behave like true and reliable companions in many ways.
- Humanoids are robots so adaptable and flexible that they will be rapidly used in many situations and circumstances.
- Their shape, and the sophisticated human-robot interaction, will be very useful for those situations where a human shape is needed.
- Faced with an aging population, the Japanese society foresees humanoid 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.
- Research carried out in humanoids laboratories over the world will have as a side effect the development of platforms to study the human body, for training, haptic test and trainings, with extraordinary outcomes on health care, education, edutainment, and so on.

7.1.4. Problems

- Reliability of the internal evaluation systems of robots.
- Unpredictability of robots’ behaviour.
- Traceability of evaluation/actions procedures.

- Identification of robots.
- Safety. Wrong action can lead to dangerous situations for living beings and the environment.
- Security. In cases where the autonomy of the robot is controlled by ill-intentioned people, who can modify the robot's behaviour in dangerous and fraudulent ways.

Because humanoids incorporate almost all the characteristics of the whole spectrum of robots, their use implies the emergence of nearly all the problems we are examining below. In particular, their introduction in human environments, workplaces, homes, schools, hospitals, public places, offices, and so on, will deeply and dramatically change our society.
We have forecast problems connected to:

- Replacement of human beings (economic problems; human unemployment; reliability; dependability; and so on)
- Psychological problems (deviations in human emotions, problems of attachment, disorganization in children, fears, panic, confusion between real and artificial, feeling of subordination towards robots).
- Well before evolving to become conscious agents, humanoids can be an extraordinary tool used to control human beings.

7.1.5. Recommendations

Activate working groups inside Standards Committees to study the possibility to define international technical/legal rules for commercial robots regarding:

- Safety. We should provide for systems for the control of robots autonomy. Operators should be able to limit robots autonomy when the correct robot behaviour is not guaranteed.
- Security: H/W and S/W keys to avoid inappropriate or illegal use of the robot
- Traceability: like in the case of sensitive systems, we should provide for systems like the aircraft's black box, to be able to register and document robot's behaviours.
- Identifiability: like cars and other vehicles, robots too should have identification numbers and serial numbers.
- Privacy: H/W and S/W systems to encrypt and password-protect sensitive data needed by the robot to perform its tasks or acquired during its activity.

Promote cross-cultural updates for engineering scientists that allow them to monitor the medium and long-term effects of applied robotics technologies.

Promote among robotics scientists the spirit of the Fukuoka World Robot Declaration (2004):

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

7.2. Advanced production systems

7.2.1. Industrial robotics

An industrial robot is officially defined by ISO as an automatically controlled, reprogrammable, multipurpose manipulator.
Complexity can vary from simple single robot to very complex multi robot systems:

- Robotic Arms

- Robotic Workcells
- Assembly Lines

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.

Industrial robotics is the main field of research, application and manufacturing. “In 2004, 17% more robots were sold than in 2003 (…) A robust growth in robot installations worldwide between 2005 and 2008 can be expected” (*source*, IFR/Unece 2004)

7.2.2. Benefits

- Increase productivity (speed, endurance)
- Increase quality (precision, cleanness, endurance)
- Make possible highly miniaturized devices
- Substitute for humans in dangerous, heavy, de-humanising jobs

7.2.3. Problems

- Loss of workplaces
- Technical dependability

7.2.4. Recommendations

- Welfare politicies to facilitate workers’ reconversion
- Education programs to create new skills

7.3. Adaptive robot servants and intelligent homes

7.3.1. Indoor Service Robots

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

- Cleaning and housekeepers: fast and accurate, never bored;
- Baby sitters: patient, talkative, able to play many games, both intellectual and physical;
- Assistants to the elderly: always available, reliable, taught to provide physical support;
- Cleaners: fast and accurate, never tired;
- Handymen: able to solve many technical problems

7.3.2. Ubiquitous Robotics

We can consider *Ubiquitous Robotics* as an extension of Domotics.
We will be living in a world where many objects will be networked to each other and a robot will provide us with various services by any device through any network. Computers will be accessible at any time and at any place; and ubiquitous intelligent machines will provide services suitable to the specific situation.
The living space will be populated by an increasing number of networked intelligent appliances and mobile robots. In the near future, living areas will be ubiquitously computerized, with sensors and computer distributed in the environment. .

Among the possible scenarios, the home robot will become a single distributed robot, able to perceive every aspect of the environment and of the beings living inside, performing every kind of task required.
The goal is the development of intelligent buildings and houses autonomously taking care of:

- heating and ventilation
- cleaning
- safety and security
- food preparation and conservation
- laundry
- communication
- entertainment
- health care
- elderly people
- disabled persons

7.3.3. Benefits:

- Better quality of life
- Increased safety and security

7.3.4. Problems:

- Technology addiction
- Safety, security, privacy
- Unpredictability of machine behaviour resulting from machine learning
- Assignment of liability for misbehaviours or crimes
- Humans in robotized environments could face psychological problems.
- Addiction

7.3.5. Recommendations

- Update safety and security standards
- Legislation should consider privacy concerns due to intelligent environments
- Need to monitor the mental health of lonely people assisted by artificial environments.

7.4. Network Robotics

7.4.1. Internet Robotics

All robots will be connected to the web, through one or more of the fast growing wireless systems.
This will permit the remote human-robot interaction for tele-operation and tele-presence. This also will permit robot-robot interaction for data-sharing and cooperative working and learning.
When the Web speed will be comparable to that of the internal LAN of the robot, the machine will explode into a set of specialised systems distributed over the net.
Complex robotic systems will be developed, consisting of teams of co-operating robotic agents/components connected through ICT and GRID technologies:

- multi-agent systems made up of identical individual robots
- multi-agent systems made up by specialised

- networked intelligence systems
- networked knowledge systems

7.4.2. Robot ecology

Robot Ecology indicates the field of research and development of self organising robot teams consisting of a large number of heterogeneous team members. The organization of robot teams or squads is needed to perform specific tasks that require automatic task distribution and co-ordination at a global and local level; and when central control becomes impossible due to large distance and lack of local information, time of signal travelling.

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

7.4.3. Benefits:

- Increased efficiency in performing complex tasks
- Capability to manage large scale applications
- Abundant and replaceable interchangeable agents
- Reliability, because the group can perform even after losing most of its parts.

7.4.4. Problems:

- Dependability of primary services on complex systems.
- Unpredictability of robot team behaviour
- Assignment of liability for misbehaviours or crimes
- Hacker vulnerability
- Privacy

7.4.5. Recommendations

- Update international fault tolerance standards to take into account cross-effect complexity

7.5. Outdoor Robotics

Robots to explore, develop, secure, and feed our world and worlds beyond

7.5.1. Land

- Mining (automated load-haul-dump trucks, robotic drilling and blasting device).
- Cargo Handling (cranes and other automation technology for cargo lift on/lift off)
- Agricultural (autonomous tractors, planters and harvesters, applicators for fertilisers 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 (Robot for pollution cleaning and dangerous plants decommissioning)

7.5.2. 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 ultra deep waters
- Search & Rescue (underwater robots for first response intervention in casualty at sea, like submarine run aground)

7.5.3. Air

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

7.5.4. Space

- Space Exploration (deep space vehicles, landing modules, rovers)
- Space Stations (autonomous laboratories, control & communication facilities)
- Remote Operation (autonomous or supervised dexterous arms and manipulators)

7.5.5. Benefits

- Robots could be employed in dangerous operations (laying explosives, going underground after blasting to stabilize a mine roof, mining in areas where it is impossible for humans to work or even survive)
- Especially mobile robots can be highly valuable tools in urban rescue missions after catastrophes like earthquakes, bomb- or gas-explosions or daily incidents like fires and road accidents involving hazardous materials. The robots can be used to inspect collapsed structures, to assess the situation and to search and locate victims).
- More efficient exploitation of natural resources
- Face food production for increased earth population
- Expand earth and space knowledge

7.5.6. Problems

- Excessive anthropization and exploitation of the planet
- Threat to all the other forms of live on the planet
- Technology addiction
- Technology dual-use: Possible reconversion of civilian robots to devices for military and misuses (terrorism, pollution)

7.5.7. Recommendations

- Environmental organizations should promote researches on the impact of the new robotic technologies on nature
- Scientists should monitor the impact of heir technologies.

7.6. Health Care and Life Quality

7.6.1. 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 room 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 July 11, 2000, FDA approved the first completely robotic surgery device.

Typical applications are:

- Robotic Telesurgical Workstations
- Robotic devices for endoluminal surgery
- Robotic systems for Diagnosis (TAC, RMN, PET, …)
- Robots for Therapy (Laser eye treatment, Targeted Nuclear Therapy, Ultrasonic surgery…
- Virtual Environments for Surgical Training and Augmentation
- Haptic interfaces for surgery/physiotherapy training

7.6.2. Bio-Robotics

The design and fabrication of novel, high performance bio-inspired machines and systems, for many different potential applications; and to develop (nano, micro, macro) novel devices that can better act on, substitute parts of, and assist human beings, such as in diagnosis, surgery, prosthetics, rehabilitation and personal assistance.
Biomechatronic human prostheses for locomotion, manipulation, vision, sensing, and other functions:

- artificial limbs (Legs, Arms, …)
- Artificial Internal Organs (Heart, Kidney, …)
- Artificial Senses (Eye, Ears…)
- Human Augmentation (exoskeleton,

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

7.6.3. Assistive Technology

Personal robots in clinics or at home for the care of:

- Patient
- Elderly
- Handicapped

7.6.4. Robotics in computational biology

Micro/nano technologies and robots in medicine and biology

7.6.5. Benefits

- Minimally invasive surgery reduces patient recovery time.
- Improved accuracy and precision
- Robotics systems increase precision of microsurgery
- Robotics enhance the performance of complex therapies
- Bio-robotics will enhance the life quality after diseases or accidents
- Assistive technology will help many people to conduct a more independent life
- Surgical robots can restore surgeon’s dexterity.

7.6.6. Problems

- expense of the robotic systems
- dependability
- reduced dexterity, workspace, and sensory input to the surgeon
- breakdown of surgical robot systems can cause potentially fatal problems
- Issues of size, cost, functionality

7.6.7. Recommendations

- Create cross committee with bioethics people
- high security and reliability

7.7. Military Robotics

7.7.1. Intelligent Weapons

In this field are comprised all the devices resulting from the development of traditional systems by using robotics technology (automation, artificial intelligence, and so on)

- Integrated Defence Systems: A.I. system for intelligence surveillance, and controlling weapons and aircraft capabilities.
- Autonomous Tanks: armoured vehicles carrying weapons and/or tactical payloads.
- Intelligent Bombs and Missiles.
- UAVs (Unmanned Aerial Vehicles): unmanned spy planes and remotely-piloted bombers.
- AUVs (Autonomous Underwater Vehicles): intelligent torpedoes and autonomous submarines.

7.7.2. Robot Soldiers

Humanoids will be employed as substitute for humans in the performance of "sensitive" tasks and missions in environments populated by humans. The main reasons for using humanoids is to permit a one-by-one substitution, without modifying the environment, the human/human interaction or the engagement rules. This could be required where safeguarding human life is considered a priority.

- Urban Terrain Combat
- Indoor security operations.
- Patrol
- Surveillance

7.7.3. Superhumans

There are several projects to develop a superhuman soldier. Actually, the human body cannot perform tasks with the strength, the speed and the fatigue resistance of the machines.
A*ugmentation* will make possibile to extend human's existing capabilities through wearable robot exoskeletons, to create superhuman strength, speed and endurance.

- Artificial Sensor Systems
- Augmented Reality
- Exoskeletons

7.7.4. Benefits:

- Tactical/Operational strength superiority
- Unemotional behaviour, potentially more ethical than humans.

- Limited loss of human lives in the Robotized Army
- Better performances of superhuman vs. human soldiers

7.7.5. Problems:

- Inability to manage the unstructured complexity of a hostile scenario
- Unpredictability of machine behaviour from machine learning
- Assignment of liability for misbehaviours or crimes
- Humans in mixed teams could face psychological problems.
- Practical and psychological problems having to distinguish humans from robots.
- Overstress and de-humanization of superhuman soldiers.

7.7.6. Recommendations

- Promote public debate on the dynamics and problems facing democracies.
- Promote critical thinking and awareness among robotics scientists involved in military driven research programs, to sharpen the monitoring of the potential threats to humankind.
- Create working groups inside existing organisations for compliance with international regulations.

7.8. Edutainment

7.8.1. Educational Robot Kits

The beneficial applications of Robotics in education are known and documented.
In the age of electronics, computers and networks, it is necessary to modernize not only the content and tools, but also the educational methods of 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, youth 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 on location and time.
Youth spend more time playing videogames, playing with mobile phone or downloading file from the Internet. These activities provide them with experiences which are now at the same levels as the most sophisticated technological systems. All this has accelerated the pace of life, so much so that flow of human experience is now both real and virtual. In fact, we are entering the age of cyber-space, 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 support tools (books, documentaries, etc.) are at risk of becoming unsuitable when compared with the everyday possibilities offered to young people by the world of the new mass media. Therefore, it is necessary to begin to plan new ways to transmit knowledge which exploit the potential of new technologies.
Robotics is a very good tool through which to teach technology (and many other subjects) while, at the same time, always remaining very tightly anchored to reality. Actually, robots are real three-dimensional objects which move in space and time, and can emulate human/animal behaviour; but, differently from video games. They are real machines, true objects, and students learn much more quickly and easily if they can interact with concrete objects and not simply formulas and abstract ideas.

7.8.2. Robot Toys

Aibo robot is Sony's peppy robotic dog with a software-controlled personality, and abilities. The entertaining robot, which cost upwards of $2,000 each, can dance, whimper, guard and play, developing personalities based on interaction with their 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) with a sort of forward-and-down movement.

7.8.3. Entertainment

Robots will enable us to build real environments which may be either the perfect (or scaling) copies of existing environments, or reconstruction of settings that existed centuries/millennia ago, and which we can repopulate with real or imaginary animals.
Robots and robotics settings will make it possible to recreate natural phenomena and biological processes, even harsh and 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 advertise corporate logos, products, and as feature attractions in public events. They are marketing tools manufacturers show off on special occasions.
Last, but not least, robots will be used as sexual partners in many fields, from therapy to prostitution.

7.8.4. Robotic Art

The role of robotics in contemporary art, along with other 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 actuators and sensors in response 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 a special fascination on people everywhere.
Robots can be used as tools in art and enable the building of artistic works in shorter times, thus expanding the boundaries of human creativity.
Robots can also perform actor's roles and play works of art.

7.8.5. Benefits:

- 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 methods of reasoning and a powerful tools for grappling with the world.
- Robotics collects all the competencies needed for designing and constructing machines (Mechanics, Electrotechnics, Electronics), computers, software, systems of communications, 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 (Math, Physics, Technical Drawing).
- Roboticics construction kits, combining the physical building off artefacts with their programming, can foster the development of new ways of thinking that encourage new reflections on the relationships between:
- life and technology;
- science and its experimental toolset;
- robot design and values and identity.
- Robot toys can be intelligent toys: They can be specifically designed to stimulate kids' creativity and the development of their intellectual faculties;
- Robot toys can become kids' companions, and – for only children – can play the role of "friend", "brother", or the traditional "imaginary friend";
- Robot toys could be used in the pedagogical assistance of autistic children.
- Sexual robots could decrease the sexual exploitation of women and children.

7.8.6. Problems:

- Robot Toys could cause psychological problems:
    - Loss of touch with the real world.
    - Confusion between natural and artificial
    - Confusion between real and imaginary
    - Technology addiction
- Sexual robots could raise problems related to intimacy/attachments.
- Concern about safety and reliability
- Dissemination of misinformation
- Technology can prevail over creativity

7.8.7. Recommendations

- Educational systems should incorporate Robotics in their programs
- Educational systems should monitor the effects of Robotics in students' learning
- Psychologists should monitor the effects on kids of Robot toys
- Consumer organizations should monitor the safety of the robotics products (reliability, privacy).

7.9. Final Recommendations

We recommend the following further steps:

- Introduce Roboethics issues to the fields of investigation of the European Group of Ethics
- Promote a transdisciplinary and cross-cultural Roboethics Community, along the lines of the Bioethics Committees
- Open a Roboethics Special Interest Group inside EURON - European Robotics Research Network.
- Promote popular discussion of roboethical issues to increase public awareness.

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Send any comment to info@scuoladirobotica.it

Scuola di Robotica

C.P. 4124 - P.za Monastero, 4

16149 GENOVA - ITALY