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Robo-Ethics
A Survey of developments in the field and their implications for social effects

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Abstract: Robotics unifies two disciplines: Science and humanities. The effort to design roboethics should make the unity of these two disciplines 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.

Some decades ago social aspects of robotics were discussed. Because of the results and the rapid development of this field ethical issues became more and more important. Therefore the term roboethics was introduced in the literature. The main goal of this contribution is to present and discuss this subject, probably at the first time, from the viewpoint of robotics.

First an overview from a practical, robotics viewpoint will be given including an outlook on Production 4.0 (5.0). Then a short presentation of currently and in the future available robots and some ideas about the ethical problems are discussed. Special emphasis is on the ethical behavior of the system "human-robot" and "End of Life – EoL" management.

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1. ROBOTS

Fig. 1 shows an overview on currently or in the future available robots. "Unintelligent", stationary industrial robots are used mostly in production systems equipped with NC (numerical controlled), machines as well as in CIM (computer integrated) - or ims (intelligent manufacturing) - systems. Currently there are worldwide approximately 2,3 million working in industry. With a 7th and 8th axis they can be limited movable to extend the working space. They are nowadays equipped with simple external sensors for "intelligent" operations e.g. assembly and disassembly, fuelling cars… and are called "intelligent" robots.

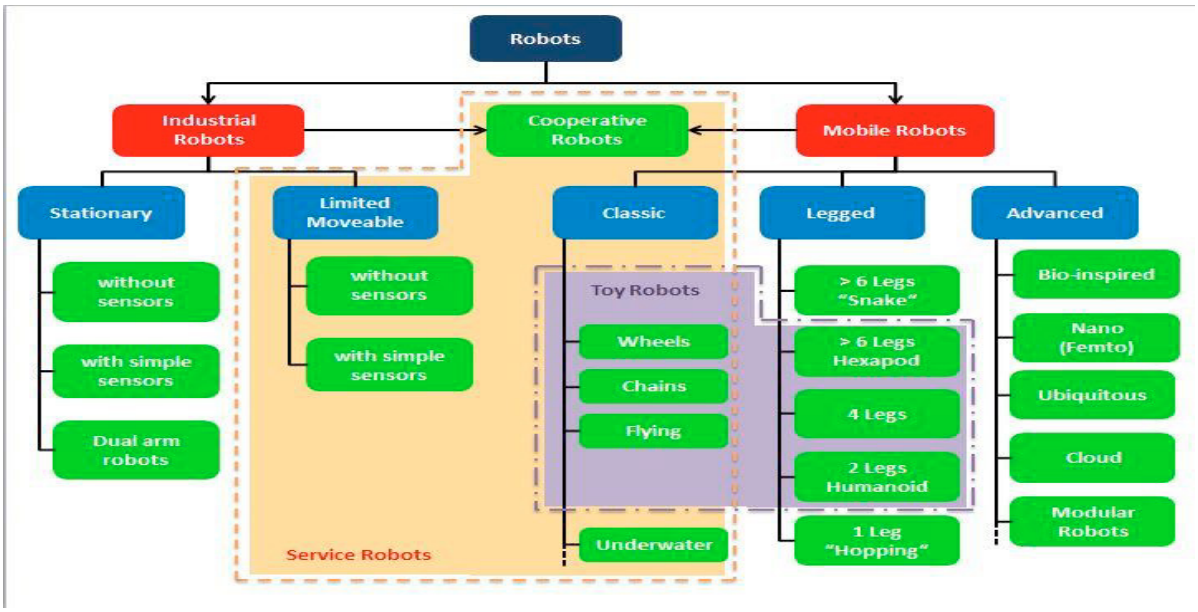

Fig.1 Categorization of Robots (Kopacek 2018)

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Mobile robots could be divided in three categories. “classic” mobile robots are partially intelligent mobile platforms. As “Autonomous Guided Vehicles – AGV`s “ they are available since some years in industry and equipped with additional external sensors (Intelligent Autonomous Guided Vehicles – Intelligent AGV`s) covering a broad application field.
Movement possibilities are wheels, chains…… . Intelligent industrial and mobile robots are used for service tasks – “service robots” „Service robots“ are mobile robots adapted for service tasks: like for personal use - e.g. cleaning robots, lawnmowers, for healthcare e.g. assistance for handicapped, for leisure and hobby, e.g. game playing, sports (soccer,…).

“Advanced” mobile robots are currently in development and exist mostly as prototypes. Some of them will be discussed later.

Walking machines or mechanisms are well known since some decades. Usually they have more than 6 (snake), 4 (multiped) to 6 (hexapod) , 2 (biped) or one leg (hopping) degrees of freedom (DOFs). Walking on two legs is from the view point of control engineering a complex stability problem. Biped walking machines equipped with external sensors are the basis for “humanoid” robots. Some prototypes of such robots are available today.

One of the current trends in robotics is cooperation. Industrial robots are connected by their controllers for synchronisation or controlled by one controller. Latest developments deal with a modularization of the robots as well as the control system and collaborative robots (Cobots) for a save cooperation with humans.

Mobile platforms with external sensors are available since some years and cover a broad field of new applications. They are the basis of mobile robot platforms. On such platforms various devices, like arms, grippers, transportation equipment, etc., can be attached.

Possible applications including tele-operation or semi-autonomous operation of robot platforms in various scenarios could be: factory automation: operation in hazardous environments, planetary and space exploration, deep-sea surveying and prospecting, services….

Biped walking robots are much more flexible than robots with other movement possibilities. The main advantage of legged robots is the ability to move in a rough terrain without restrictions like wheeled and chained robots. Legged robots can work in environments which were until now reserved only for humans. Especially fixed and moved obstacles can be surmounted by legged robots. In addition to walking such robot could realize other movements like climbing, jumping… Intelligent robots – especially intelligent, mobile platforms and humanoid robots are able to work together on a common task in a cooperative way (Kopacek, 2012a).
Because a robot with most of the DOF`s of a human is economically not to realize with the currently available technologies there is currently a trend to develop “Single purpose” humanoid robots like for parcel delivery.

2. PRODUCTION 4.0

Production 4.0 combines production methods with state-of-the-art information and communication technology. The driving force behind this development is the rapidly increasing digitization of the economy and society. It is changing the future of manufacturing and work. In the tradition of the steam engine, the production line, electronics and IT, smart factories are now determining the fourth industrial revolution.

The technological foundation is provided by intelligent, digitally networked systems that will make largely self-managing production processes possible: In the world of Production 4.0, people, machines, equipment, logistics systems and products communicate and cooperate with each other directly. Production and logistics processes are integrated intelligently across company boundaries to make manufacturing more efficient and flexible. It is driven by:

Rise in data volumes

Computational power

Connectivity

Virtual to real world data transformation

One of the main goals of production 4.0 are “Smart Factories”. They beginning to appear and employ a completely new approach to production. Smart Factories allow individual customer requirements and the dynamic business and engineering processes enable last-minute changes to production.

These smart products are

- uniquely identifiable,
- may be located at all times
- know their own history and the current status
- able to find alternative routes to achieving their target (final) state

3. ROBOTS IN PRODUCTION 4.0

Clearly this new automation philosophy requires highly cooperative industrial, mobile and probably in the future humanoid robots – a so called multi-robot system.
A multi-robot system is a distributed system that consists of a collection of autonomous computers, connected through a network and distribution middleware which enables them to coordinate their activities and to share the resources of the system so that user perceives the system as a single, integrated computing facility. Nevertheless, multiple robot systems are different from any other distributed systems because of their implicit “real world” environment, which is more difficult to model.

The term collective behavior denotes any behavior of agents in a system having more than one agent. Therefore, cooperative behavior is a subclass of collective behaviour characterized by cooperation, this is, the ability to work or act together for a common purpose.
Hence it follows that a multi- robot system displays cooperative behavior if due to some underlying mechanism, there is an increase in the total utility of the system. There are three fundamental aspects for cooperative behavior: the task the robots must perform, the mechanism of cooperation and the system performance.
In order to perform such collaborative tasks Cobots are designed to be safe around humans (using sensors, force limiting and rounder geometries than traditional robots), to be lightweight (for them to be moved from task to task) and to be easy to implement and use without skills in programming. Above all, a collaborative robot is not a replacement robot; it assists workers rather than replaces them.
As detailed by the international ISO10218 standard, robots can have four types of collaborative features. These are

Safety Monitored Stop,
Hand Guiding,
Speed and Separation Monitoring and
Power and Force Limiting.

Safety Monitored Stop is implemented in environments where the robots operate mostly alone, with occasional human interference. The feature will cause the robot to pause (though not shutdown) when the safety zone is violated (i.e. a human enters its workspace).
The speed and separation monitoring feature is an extension of Safety Monitored Stop. Instead of adopting a single behavior throughout the robot's entire workspace, the latter is gradated into several safety zones.
Hand Guiding enables the robot to move while the worker is in its workspace (as is possible with Speed and Separation Monitoring). Using an end-of-arm device capable of detecting applied forces, the robot can be guided by a worker for hand guiding and rapid path teaching.

Power and Force Limiting feature is probably the safest of them all as this type of robots are purposefully designed to operate around humans rather than adapted to do so. As the name suggests, the forces and energy applied to a human are limited so as to avoid any inflicted harm.
The real time of Cobots will come in Production 5.0.

4 ROBOETHICS

The process of engineering is the process of creating solutions that can simultaneously achieve the goals of the problem and remain within certain constraints. These goals and constraints are referred to as "design drivers". The three most common "design drivers" are

the cost of the solution,
the schedule of the project and
the features of the solution.

These drivers can act as either goals or constraints, depending on the situation.

Ethical considerations can similarly be viewed as "design drivers", constraints or goals. Ethical behavior is either something to be sought or something used to limit the design space. The technical features are analogous to the moral issues at stake in an ethical case. Usually as the roots of Roboethics are the Isaac Asimov's 3 Laws of Robotics:

First Law: A robot may not injure a human being, or, through inaction, allow a human being to come to harm.
Second Law: A robot must obey orders given it by human beings, except where such orders would conflict with the first law.
Third Law: A robot must protect its own existence as long as such protection does not conflict with the First or second law.
Asimov added the *Fourth Law (Law Zero)*: No robot may harm humanity or, through inaction, allow humanity to come to harm.

These laws are very simple, but Asimov shows in some of his short stories, which conflicts and contradictions would result in practice. A conflict results e.g. obviously from the fact that such robots could hardly be used for martial purposes. The military has naturally a very large interest in intelligent machines and promotes their development very actively.

How one can deal with the fact that a robot will have some times incomplete information. A human could say to a robot, to give poison in a glass of water. To another robot you say the he should serve the glass to a special human. None of the two robots notices that he offends against the 1st law. Incomplete information can evoke fatal errors (Veruggio, 2009).

Until now robotics was a discipline based on: Mechanics, Physics, Mathematics, Automation and Control, Electronics, Computer Science, Cybernetics, Artificial Intelligence… Therefore robots are frequently used as examples for Mechatronic Systems. For Roboethics nontechnical fields e.g. Philosophy, Ethics, Theology, Biology, Physiology, Neurosciences, Law……have to add.

Robotics unifies 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.

They can achieve the vision of the Robotics' future. Robotics scientists, researchers, and the general public have about robots different evaluations:

- Robots are nothing but machines
- Robots have ethical dimensions
- Robots as moral agents
- Robots, evolution of a new specie

Currently the following definition is used:
"Roboethics is an applied ethics whose objective is to develop scientific/cultural/technical tools that can be shared by different social groups and believes. 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." (Veruggio, 2008).

In Tab.1 selected examples for robots and their applications are listed concerning ethical issues.

Tab 1 Selected applications adapted from (Kopacek, 2018)

Applications	Benefits (examples)	Problems	Ethic Recommendations
Exploring Robots	Robots could be employed in dangerous operations	Threat to all the other forms of live on the planet	Environmental organizations should promote researches on the impact of the new robotic technologies on nature
Health Care and Life Quality	Minimally invasive surgery reduces patient recovery time	Breakdown of surgical robot systems can cause potentially fatal problems	Improve the TQM standards including ethics.
Service Robots	Increasing the quality of human life.	Psychological problems; Loss of privacy.	Make the robots more "human friendly". The robot have to be a "friend".
Toy Robots (Edutainment)	Robot toys can become kids' companions, e.g. "friend", "brother"..;	problems related to intimacy.	Educational systems should incorporate this type of robots in their programs. Make sure that there are real human friends.

The main goals of Roboethics are:
Avoid conflicts
Work for a safe future
Protect the environment
Select materials that require minimum energy to produce,
Select processes that minimize waste of materials and energy,
Design parts that can be recycled or reused,
Design products that can be readily disassembled to recover the parts,
Design products that minimize the use of hazardous and toxic materials,
Give attention to how the product will be disposed of at the end of its useful life.

A very good example for "Work for a safe future" and "Protect the environment" is reduce and recycle the waste of electrical and electronic equipment (WEEE). It is the fastest growing form of waste in Europe. However, such discarded material contains significant amounts of raw materials described as critical metals that can be profitably recycled.

Critical metals availability is essential for high-technology, green and defense applications, but they are vulnerable to fluctuations in supply.
The EU-funded HYDROWEEE DEMO project focused on the recovery of base and precious metals from WEEE using innovative hydrometallurgical processes. The initiative built on an earlier EU project that developed processes using

sulfuric acid to extract valuable metals from lamps and cathode ray tubes (CRTs), liquid-crystal displays (LCDs), lithium-ion batteries, printed circuit boards (PCBs) and industrial catalysts (Kopacek & Kopacek,2012b). Project partners improved techniques for extracting 11 different metals, including gold and silver, and created new ways to recover a further 6 metals. The new processes can produce materials with sufficient purity (above 95 %) to be put on the market and reused by industry for applications such as for electroplating.

Making the plant mobile by putting it in a container allows several small and medium-sized enterprises (SMEs) to benefit from the same plant at different times, thereby reducing both waste and the financial investment required. By making the processes universal, different input materials can be treated in the same mobile plant in batches (CORDIS, 2017).

5. SOCIAL ASPECTS

In most industrialized countries, more managers than ever - along with their wealth of experience - are retiring every day, just when a solid knowledge base is increasingly important for production. The group of 50- to 64-year-olds makes up

about 20 percent of the population in the European Union today. Loss of know-how: This industrial renaissance is now at risk as the change of generations threatens a serious loss of experience and knowledge
To realize these new tasks especially education is absolutely necessary.
Production 4.0 is bringing lasting changes in the workplace. Technologies that connect things, data and processes are placing new demands on employees and management, especially in industry. Workplace training for Production 4.0 is thus the key to the success of industrial enterprises. The implementation of the digital transformation possesses are particular challenges for SMEs.
At the same time, however, Production 4.0 is making new, digital continuing professional development formats available that allow training content to be precisely tailored to the knowledge and needs of staff and management.
The constantly changing list of skills required for Production 4.0 must be regularly updated so that the relevant adjustments in the education system can be made. In the future, the focus will be on interdisciplinary thinking and acting, cross-functional process know-how, and IT skills involving both specialized and more general application knowledge
The goal should be to prevent a twofold digital divide between large and small industrial enterprises and between high-skilled and low-skilled workers. SMEs should receive special support to help them develop the skills needed for Production 4.0. (Acatech, 2016).

What about the workers – in the future, will people vanish from the factories with machines taking over?

- Well educated employees will play a much larger role because of the progress in AI and the enormous volumes of data.
- People have to:
  - managing unforeseeable events, or
  - deriving new and creative ideas from experience.

Kopacek & Hersh (2015).

6. SUMMARY AND OUTLOOK

After a short introduction on robots the necessary basic ideas of production 4.0 are presented from the viewpoint of ethical and social aspects. The role of robots in form of cooperative robots (Multi- agent systems) is shortly outlined.
Roboethics was introduced 2002 but until some years ago only dominated by publications from researchers with a non-technical background like Philosophy, Ethics, Theology, Biology, Physiology, Neurosciences, Law……Therefore Roboethics is presented from a technical viewpoint (Veruggio, 2005).
According to the main goals of roboethics avoid conflicts, work for a safe future and protect the environment an example was shortly described.
The social aspects of Production 4.0 are similar of those during the introduction of robots in manufacturing automation in the eighties. A dramatic loss of work places: "Army" of unemployed people, the "manless" factory, robots as jobkillers,…… was predicted. Clearly some "low tech" working places disappeared as usual in automation. At that time these problems were solved mainly by higher education of the employees and increasing the production output.
We all hope that it will be also true for Production 4.0.

In my personal opinion there are some other open questions like the costs for installation and maintenance especially for SME`s, the return of investment (ROI) and tailormade education offers for the future operators of Production 4.0 systems and in the future Production 5.0 and 6.0.

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