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Humanoid robots Robotainment

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Abstract: The field of humanoid robots is currently overwhelming. Therefore it is necessary to give an overview by arranging these robots in groups. Until now there was only a first trial from the commercial side in 4 categories (Professional, Amateur, Toy and Cost Oriented Robots).

The present work tries to propose a meaningful classification of actually available humanoid robots being stable at least for some time from a technological viewpoint. Four groups are generated according to their main tasks Robotainment ("Fluffy"), Infosistance ("Hero"), Rescue ("Buddy") and AI ("Mr.Brain").

These sample groups involve 14 species, which are presently available and produced by some Universities and Companies. Exemplarily they are classified into the given groups. Further developments associated with artificial intelligence might merge those groups, still keeping the main orientation of their aims. This might be seen as the limitations of (any) today's classification of humanoid robots. Based on the results some "Cost Oriented Humaoid Robots – COHR" can be identified and compared.

Finally ethical and social aspects of humanoid robots will be outlined and discussed.

Keywords: Intelligent Systems and Applications, Robots, Cost Orientation, Humanoid robots, Roboethics

1. INTRODUCTION

Robots are always frequently used as an example for Mechatronic Systems. Currently the field of robotics is very fast growing. An overview is shown in Fig. 1.

In Fig.1 humanoid robots are mobile, legged robots which are used for service and toy tasks. Furthermore, dual arm robots can be seen as a combination of industrial and humanoid robots but because of their industrial applications they are assigned to Industrial Robots.

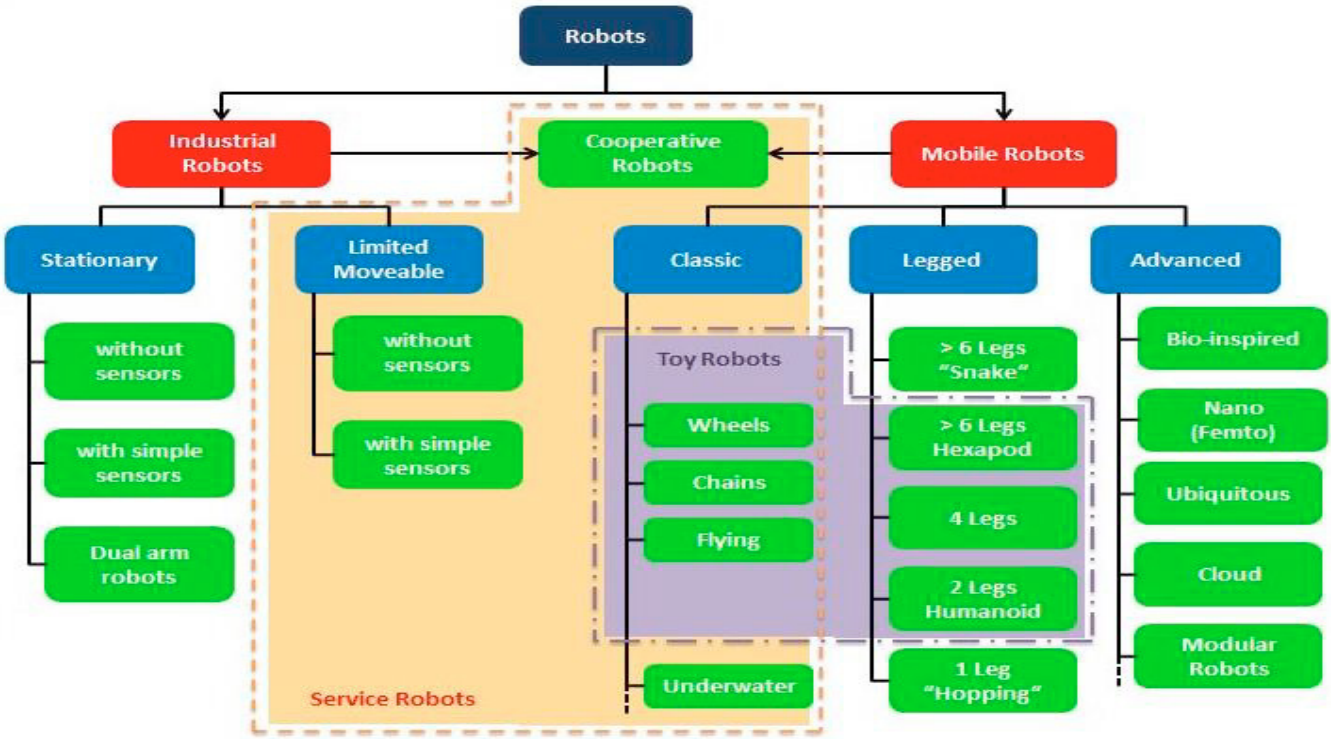

Fig. 1 Categorization of Robots (Kopacek, 2018)

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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.

Examples are Dual arm robots, cooperative robots, fully autonomous mobile robots, snake robots, bioinspired, Nano-, Femto-, Atorobots.

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

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

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

In addition to learn about their environment, robots have also to learn about their own behavior, 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, trying and error, learning by doing, ……..).

21th century robots will be used in all areas of modern life. The major challenges are:

- To develop robotic systems that can sense and interact useful with humans.
- To design robotic systems able to perform complex tasks with a high degree of autonomy.

The role of these robots of the future could be improved by embedding them into emerging IT environments characterized by a growing spread of ubiquitous and cloud computing, communications and of ad-hoc networks of sensors forming what has been termed "ambient intelligence".

2. HUMANOID ROBOTS

Humanoid robots are robots whose body shape resembles the human body. This can mean an entire body with arms and legs or just single body parts. Androids are especially designed humanoid robots. They are built to aesthetically remind of humans.

The definition of a humanoid is simply "having human characteristics." That is exactly what humanoid robotics is about. According to recent studies, humanoids will be able to show emotion, think for themselves, and learn by watching their surroundings. It was always a dream to have a personal robot looking like a human.

Main features of humanoid robots are:

- biped walking
- voice communication – speech recognition
- facial communication

Therefore, humanoid robots need to have a torso with a head, two arms and two legs, although some forms of humanoid robots may model only part of the body, for example, from the waist up. Humanoid robots may also have a 'face', with 'eyes' and a 'mouth'.

Main problems in humanoid robots are currently:

- Each movement possibility (Degree of Freedom – DOF) is actuated on humans by muscles. In robotics at present each DOF must be realized by an electric motor, a gear without backlash and a high reduction ratio and a controller. We are looking forward until usable artificial (nano-, femto or atorobots) muscles will be available.
- An unsolved problem for all autonomous mobile robots is the power consumption. We are waiting for the next generation of batteries.
- There are currently no real industrial applications for humanoid robots.
- The minimum development time of a humanoid robot is at present 20 man-years. Therefore they are very expensive compared with their features.

With new technologies and new theoretical methods two legged robots can be realized, responsible for human tasks like service applications, dangerous tasks, tasks on the production level, support of humans in everyday life….space applications.

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 moving obstacles can be surmounted by legged robots. In addition to walking, such robots 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, 2012).

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

As the number of humanoids increases, the collective population of humanoids will learn, develop and perhaps eventually reproduce themselves more effectively. Once we have a large population of self-motivated agents attending to

separate tasks, these agents will negotiate, exchanging tasks and resources in mutually beneficial ways.

3. CATEGORIZATION

In the following the commercial and technological categorization will be outlined and shortly discussed, and the new term "Robotainment" will be introduced.

3.1 Commercial viewpoint.

Currently there are worldwide four categories of two legged humanoid robots available:

"Professional" humanoid robots developed by large companies with a huge amount of research capacities. Examples are: The Honda robots (P1, P2, P3, ASIMO) – with the idea to assist humans in everyday working, the SONY robots (SDRX and QRIO) – with the background to serve mostly for entertainment, leisure and hobby or in the future as personal robots.

"Research" humanoid robots: There a lot of such robots currently available or in the development stage e.g. approximately worldwide more than 1000 University institutes and research centers are active in this field. The robots of this category are usually prototypes developed by computer scientists to implement methods of AI, image processing, theoretical scientists from mechanics implementing and testing walking mechanisms, control scientists to implement new control strategies, social scientists to implement human machine interfaces (HMI) for an efficient communication between humans and humanoid robots.

Humanoid "Toy" robots: There are a lot of humanoid toy robots, mostly developed by small or medium sized companies, available on the market. Usually they have extremely limited capabilities in hard- as well as in software. Usually the basic programming software is simple – no advanced knowledge of programming is necessary. They can walk, run, do flips, do cartwheels and dance. These robots are mostly available as a kit or pre-assembled, ready to walk.

Because of the limited market and the high price of professional humanoid robots, the availability of research humanoid robots, and the limited capabilities of humanoid toy robots, a new fourth category – *Cost Oriented Humanoid Robots (COHR)*, was introduced (Kopacek, 2011). These robots will be able to support humans in everyday life e.g. on the working place, in the household, in leisure and entertainment and should be available on the market for a reasonable price. These goals could be reached by standardization of the hard- and software platform, using the latest technologies, applying modern control concepts, ... (P. Kopacek, M. Hersh, 2015), (Kopacek, 2011).

To support humans in everyday life like working place, household, ... , cost oriented humanoid robots (COHR) must have an appropriate size (minimum 1.2m) as well as much more functionality then the currently available toy robots. The software has to be "open" for easy adapting according to the special demands of the user. The price should be not more than the price of a currently available, expensive toy robot. Probably COHR are a first step to one of the oldest dreams of the humans – the Personal Robot.

3.2 Technological viewpoint.

This chapter is based on 14 different humanoid robots, which are presented and described in their technical details in Linert, 2017. They will be used as references for a classification of humanoid robots.

The technical characteristics and descriptions were extracted from the manufacturers and/or universities documents and service sites, as far as they are openly available and not kept secret (which might be the case for some species under development, to keep patent rights).

Based on the results four groups Fluffy, Buddy, Hero and Mr. Brain were created. For each robot in these groups the specifications Height, Weight, Controller/CPU, Operating System (OS), Programming languages, External Power Supply, Battery, Operating time, Degrees of Freedom, Sensors, Connectivity and Actuators are collected, if available, in a table and some of them compared in a summary table (e.g. Tab.1).

3.2.1 Robotainment ("Fluffy")

The main purpose of this group of robots is to entertain and educate, both usually appearing more or less in combination. The term "Robotainment" in modification of "Edutainment" (Linert & Kopacek, 2016) may well characterize the properties of this group. Evaluated robots may serve as representative for the *Fluffy* class: Bioloid Premium, RoBoHoN, NAO, Poppy and Qrio.

As mentioned before the main aim of *Fluffy* robots is to entertain and educate (edutainment). In general they are rather small (<1m) and weigh less than 10 kg. Furthermore, they have many different functions and sensors. For instance, Bioloid, NAO and Poppy can be customized with different additional sensor packages. They are also used in competitions, such as the Robo Cup. Therefore they can be programmed with common programming languages such as C/C++, Python, Java or Matlab. There are also simple programming environments, like RoboPlus, for children. The robots are designed to ensure safety and durability for domestic use. As for the costs, one can distinguish the *Fluffy* robots into two groups: Low cost for private users and hobbyists, high cost mainly for universities and laboratories.

In general *Fluffy* robots

- have to be robust and stable,
- offer expandable modules,
- possess various sensors and interfaces,
- have to be able to communicate and interact,
- have to be easily programmable and usable,
- have a cute and friendly appearance and
- have to be cost oriented (for hobbyists).

Tab. 1 Comparison of the group "Robotainment" (Linert, 2017)

	Bioloid	RoBoHoN	NAO	Poppy	Qrio
Height	39,7 cm	19,5 cm	57,3 cm	83 cm	60 cm
Weight	1,7 kg	390 g	5,2 kg	3,5 kg	7,3 kg
Prog. lang.	RoboPlus, C/C++	Android	C/C++, Python, Java, Matlab	Python, Snap	-
Battery	1000 mAh 11,1V	1700 mAh 12V	48,6 Wh	-	-
DOF	18	-	25	25	38
Year	2009	2015	2006	2012	2002-2006
Costs	1100-1300€	1700€	10.000€	7.500-9.000€	Unknown (not for selling)
Aim	Edutain-ment, compe-tition	Entertain-ment, smartphone, communi-cation	Research Edutain-ment, competi-tions	Learning with creativity	Communi-cation Edutain-ment, competi-tion
Designer	Robotis South Korea	Sharp Corp. Japan	Aldebaran France	Flowers Lab France	Sony Japan

3.2.2 Infosistance ("Buddy").

Buddies are humanoid robots, which are mainly designed to communicate (in a natural way) with humans and to provide information and assistance. The term "Infosistance" may well characterise the properties of this group.

The following robots may serve as representative for the *Buddy* class: Asimo, Geminoid F, RoboThespian, Roméo and Wakamaru (Linert, 2017).

Buddies have the size of a small to average adult (100-175 cm) so they can operate in human environment without disturbing or frightening people. The *Buddy* group focuses on human like communication, which means not only to understand language and answer appropriately but also to recognize gesture and facial expressions.

ASIMO, *Roméo* and *Wakamaru* are meant to assist people in everyday life, whereas *Geminoid F* and *RoboThespian* intend to entertain and communicate with people. Therefore the first three are able to operate autonomously while the others work via tele-operation.

The android *Geminoid F* looks like a real person and is able to analyze people's reaction. Therefore it has many DOFs in its facial area. Because it only focuses on human-like communication, it is not able to walk around. The same applies for *RoboThespian*. It is only a matter of time for them to be able to walk.

3.2.3 Rescue ("Hero").

The officially proposed aim of Heros is to act in non-human environments and/or as disaster response robots after natural disasters or other incidents in which the environment may be chemically or nuclear contaminated to avoid damages on involved humans.

The following robots may serve as representative for the Hero class: Atlas, DRC-HUBO and Petman. While Petman was designed to test chemical protecting clothes, Atlas' and DRC-HUBO's main objective is to advance disaster response robotics. Petman has many sensors to simulate a human body and to observe temperature, humidity and chemical exposure. It is able to self-balance, walk and crawl but it is not meant for more difficult tasks like Atlas or DRC-HUBO. All of the three examples are made of light material (mainly Aluminum) and have a weight of 80kg to 150 kg. All three robots can be controlled via tele-operation by a human operator. Due to the high quality hardware (sensors, actuators, …) Heros are still very expensive.

3.2.4.Intelligent robots ("Mr. Brain").

Mr. Brain robots combine human mobility and artificial intelligence. AI is an exponentially growing, however controversially discussed field mainly present in cutting edge computer science. Several strategies to implement AI can be followed, which obviously can be combined with humanoid robots. It can be expected that such a development will lead to contributions to all four groups. However, Mr. Brain's conception is basically aimed to exhibit "intelligence".

The following robots will serve as representative for the Mr. Brain class: NAO, iCub and Roméo.

Mr. Brain robots might aim to move independently and help people in their everyday life. In order to look nice and friendly through their gesture, they have to move and behave human-like. People should not be scared of their appearance neither by their intellectual behavior. The latter might seriously frighten people and already leads to controversial discussions and even to science fiction artworks (movies, books,…). This brings us back to Asimov's laws. Even if his laws might (and are) be criticized, they show an extreme farsightedness of this author in a time where today's already realized developments must have been totally out of sight.

3.2.5 Outlook.

Future developments, especially due to increasing computer capacity and artificial intelligence, might raise the appearance of overlapping group properties as mentioned already before. This might lead to combinations of the introduced groups, for example the fluffy Buddy, or the intelligent Hero. Exemplarily, NAO and Roméo given above might represent a fluffy Mr. Brain and an intelligent Buddy, respectively. Merging the features of these 4 groups would yield to a "real" humanoid robot.

3.2.6 Comparison.

Even if the above four categories from each viewpoint might yield a strongly simplified picture of today's humanoid robots, they seem to cover present and probably future developments. Obviously, overlaps must occur and will

probably increase with new computer-, sensor- and mechanical developments. However, as long as we speak about humanoid robots, imitating humans one still might ask for humanoid characteristics like: "What's your profession? Are you nice? Are you kind? Are you strong? Are you intelligent? …" Under this point of view, the presently given four groups from the technical and commercial viewpoint cover a broad range of humanoid robots. Fig.2 gives a first trial about this comparison.

Fig.2 visualizes the commercial view and the technological classification of humanoid robots. The group "Fluffy" mainly coincides with Toy robots and partly (dotted line) with cost-oriented robots (not all Fluffys are cheap to run yet). The task of communication found in the Buddy's group correlate with Professional and Amateur robots. The aim of operating in non-human environments fulfilled by Heros, can also be found in the category of Amateur robots. Though there are rumors, that big companies like Honda try to construct disaster robots, presently no actual results seem to be published (dotted line). Last, but not least, development of AI can be found in every of the four commercial categories, as it is the next step to improve humanoid robotics.

4. SOCIAL AND ETHICAL QUESTIONS

In the nearest future humanoid robots will get more and more similar to real humans and therefore new ethical and social questions will be arise.

4.1 Roboethics

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 example for Mechatronic Systems. For Roboethics nontechnical fields e.g. Philosophy, Ethics, Theology, Biology, Physiology, Neurosciences, Law……have also to be taken in account.

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.

So 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 species.

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, 2002).

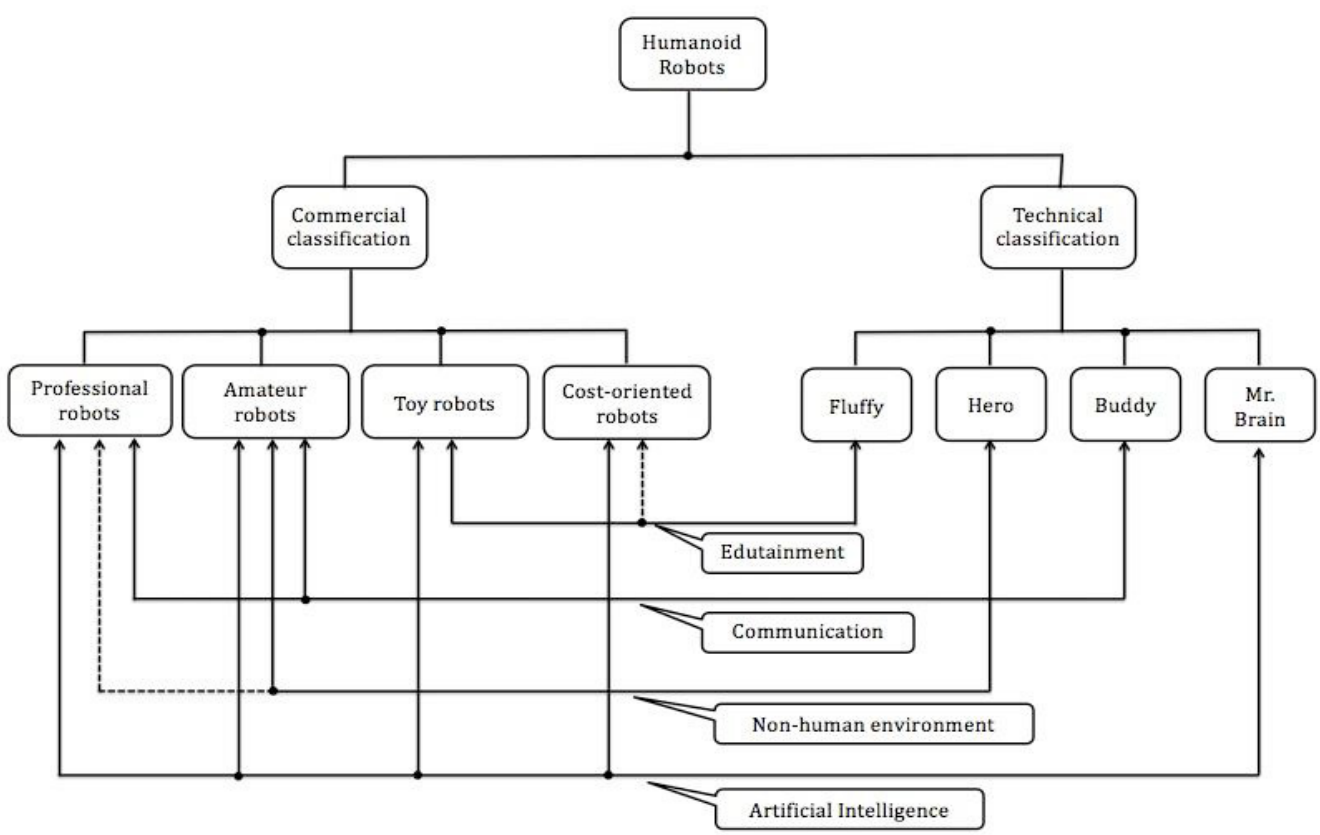

Fig. 2 Comparison of commercial and technological groups

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

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

For example an artificial intelligent system a humanoid robot, who has to know, what he has to do in a special situation. From the viewpoint of Roboethics the robot must know what to do and what not to do. Therefore a robot must act "ethically". He can do this, whom he uses activities, which lead to his goal and which have more advantages than disadvantages for others. What for a robot is applicable, is just as applicable for a human nature. Based on well-defined terms, it is possible to provide a scientific ethics and an experimental ethics and use with robots and humans. (Kopacek and Hersh, 2015.).

Humanoids are the most sophisticated thinking machine able to assist human beings in manifesting themselves, and this is ethically very good, as it supposes a radical increment of human symbolic capacity; humanoids will develop a lot of activities in order to increase the human quality of life. (Kopacek and Hersh, 2015).

4.2 Social aspects.

Future developments like "Industry 4.0", the "Internet of things", "Smart Grids", etc. will, if human development is not suddenly stopped by war or, natural or demographic catastrophes, definitely strongly change our environment. It is interesting to see that western societies like Europe or America seem to fear the takeover of our micro- and macro economic power by robotic systems by far more than Asian societies. Japan's fear of biological developed monsters, like Godzilla, appears to be deeper rooted than just a nice film idea. This difference is inherent even up to high political future governing, lobbying groups. A simple view of the external appearance today existing humanoid robots supports this observation. Western humanoid robots have generally much less nice and personal attracting appearance than their Asiatic counterparts. This cannot be only explained by "less artistic capabilities" of westerners. It is based on known or subconscious wish to distinguish humanoid robots from humans.

Let us assume that in the future humanoid robots will be able to move freely in human environment and help people with everyday activities. Beside "helping hands" – will such a humanoid robot be able to replace also social contacts? Mechanization and digitalization already turned out to have strongly changed our today's society. Humanoid robots might as well provide the ability to change our society significantly. Asimov's rules might help to direct such changes in a positive direction, however future developments will show what happens.

As engineers and researchers we tend to be fascinated and to investigate incessantly in order to improve our creations and ideas. Although, it is our duty to foresee future developments and to avoid misleading directions, it might be difficult, if not impossible, to avoid "negative" developments and applications, if our timing knowledge reaches a certain potential.

5. SUMMARY AND OUTLOOK

Future development in this area can be foreseen, on the one hand via increasing features of today's robots building parts. On the other hand, rapid developments might come from parallel research in autonomic car driving, but might also be driven by image or prestige projects showing the superior research abilities of a country. Humanoid robots used as guides in some airports, as well as waiters in bars and restaurants might fall under this aspect.

The main goal of this contribution consists of merging the two currently existing categorizations - commercial and technological – to make humanoid robots more and more similar to humans.

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