Synthesis about a collaborative project on "Technology Assessment of Autonomous Systems"

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The project started in 2009 with the support of DAAD in Germany and CRUP in Portugal under the "Collaborative German-Portuguese University Actions" programme. One central goal is the further development of a theory of technology assessment applied to robotics and autonomous systems in general that reflects in its methodology the changing conditions of knowledge production in modern societies and the emergence of new robotic technologies and of associated disruptive changes. Relevant topics here are handling broadened future horizons and new clusters of science and technology (medicine, engineering, interfaces, industrial automation, micro-devices, security and safety), as well as new governance structures in policy decision making concerning research and development (R&D).

Two main events took place during 2009: a first one was the Workshop on Autonomous Robotics in Karlsruhe (Germany), and the second one the Conference on Autonomous Systems in Caparica (Portugal). Both events were exclusively organised for this project and represented an important step for a collaboration among the two universities (KIT and UNL).

Portuguese-German Workshop on Autonomous Robotics (April 2009, University of Karlsruhe and Forschungszentrum Karlsruhe)

This first project workshop was organized by António Moniz (FCT-UNL) and Michael Decker (ITAS/Univ. Karlsruhe) and took place in Karlsruhe on the last 6 and 7 April 2009 and supported mutual knowledge on research field related with robotics, autonomous systems and technology assessment. During the meeting it was prepared the organisation of larger and public conference to be held in Portugal by the end of the year on similar topic. It included also laboratories visits.

In the first day of the workshop (6th April 2009) the discussions took place at the Research Centre Karlsruhe, ITAS (KIT North Campus), and started with presentations on the main activities the research groups are doing at FZK and at FCT-UNL (Universidade Nova de Lisboa): first, with an introduction on "Interdisciplinary TA on Robotics" by Michael Decker (FZK) and another on "Robotics and work organisation" by António Moniz and José Miquel Cabeças (UNL). The debate was enriched with the contributions from Uli Gengenbach (IAI) and a presentation on the activities on "Flexible assembly systems at

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UNL" by José Barata and Luis Ribeiro (UNL). A Lab visit at IAI (FZK) was organised by Stefan Schulz from this institute. After that the participants returned to ITAS where took place a discussion on the organisation of the conference Call for Papers, main topics, steering committee.

On the second day (7th April 2009) the workshop was held at the University of Karlsruhe campus (KIT South Campus), at the Institute of Computer Science and Engineering. There the meeting started with the presentation on "The new field group at KIT: Autonomous technical systems" by Mathias Gutmann (Institute of Philosophy, Uni. Karlsruhe) and followed by another one on "The SFB on Humanoid Robotics" by Tamim Asfour (IRA, Uni. Karlsruhe).

Also here the workshop included a laboratory visit (at IRA - Institute of Computer Science and Engineering) on the humanoid robot experiences developed there. The visit was guided by Steven Wieland from the same institute. After the visit, the participants involved again on a discussion on the main conclusions about the next steps (publications, collaborations, and the review of the main contents for the next conference in Portugal).

Conference on "Autonomous systems: inter-relations of technical and societal issues" (November 2009, Universidade Nova de Lisboa)

On November 5th was held the first annual conference of the project in Portugal, at Caparica Campus of Universidade Nova de Lisboa. The opening session of the conference was headed by the Dean of FCT-UNL, Prof. Fernando Santana and Michael Decker, Professor of KIT-University of Karlsruhe. The initial session had two presentations: José Barata (Universidade Nova de Lisboa, Faculty of Sciences and Technology, CTS) on *Robotics in Portugal. The example of European projects at UNINOVA,* and António Moniz (Universidade Nova de Lisboa, Faculty of Sciences and Technology, IET) on *Anthropocentric robotics: assessment of organisational options*. According to this author, the research activities at the European level on the concept of new working environments gave considerable attention to the challenges of the increased competencies of people working together with automated technologies. The European Commission coordinated research activities during the 80s in the field of Anthropocentric Robotic Systems that influenced the ESPRIT programme during several decades, and a wide group of European social scientist. The attention to such field does not come only after 2000 with the so-called "Lisbon Strategy" but from decades earlier, for example, with the activities at the Forecasting and Assessment in Science and Technologies (FAST) unit of DG Research. This unit paved the ground for new networks and research projects. However, more recently, the debate is also over issues that relate the working perception with autonomous systems (e.g. Autonomous robotics). Cognitive task automation may lead to over trust, complacency and loss of the necessary work environment situation awareness. This is a major constraint in complex work organizations teamwork, ending up into an operational gap, between system developments and its understanding and usability, by operators. Many concepts issued from the work organization analysis, are connected with other concepts such as motivation, alienation, satisfaction, productivity, innovation, flexibility and business processes,

learning organizations, networks and virtual enterprises. Today one can understand the wider use of the anthropocentrism concept applied to the production architectures, emerging a new value of the intuitive capacities and human knowledge in the optimization and flexibilization of the manufacturing processes. This includes also the new risk situations that occur with the use of robotic systems. We want to discuss in this presentation the need to take into consideration qualitative variables in the definition and design of robotic systems, jobs and production systems. After the debate and the lunch the participants participated in a industrial visit to Introsys, Integration for Robotic Systems-Integração de Sistemas Robóticos SA (http://www.introsys.eu), a Portuguese company in the field of robotics and autonomous systems located at Industrial Park of Moita.

The next day of the conference started with a working session with 4 presentations:

1. Christian Bauer, Ralf Mikut, Georg Bretthauer: *Movement Generation and Safety Strategies for Humanoid Robots - Acceptance Issues from an Engineers Point of View*, Institute for Applied Computer Science, Karlsruhe Institute of Technology (KIT)

2. Luis Ribeiro, José Barata, Pedro Barreira: *Is Ambient Intelligence a truly Human Centric Paradigm in Industry? Current Research and Application Scenario*, Universidade Nova de Lisboa, Faculdade de Ciências e Tecnologia

3. U. Gengenbach, G. Bretthauer: *A mechatronic system to restore accommodation*, Karlsruhe Institute of Technology (KIT) Institut fuer Angewandte Informatik

4. Diego Compagna, Stefan Derpmann, Kathrin Mauz : *The operation of autonomous mobile-robot-assistants in the maintenance area adopting the "scenario-based design" approach*, Universität Duisburg-Essen, Institut für Soziologie

In the paper of Bauer, Mikut and Bretthauer was underlined that the key role in the acceptance of humanoid robots in society is the anthropomorphic appearance of the machines. This includes not only the body shape and hardware design but also how the robot moves and handles the assigned tasks as well as the communication with the user. The collaborative research center on humanoid robots (Sonderforschungsbereich SFB-588) funded by the German Research Association (Deutsche Forschungsgemeinschaft DFG) is dedicated to develop a humanoid robot, which is capable of handling everyday work in a regular kitchen environment in cooperation with a human user. The tasks in this area of interest range from laying a breakfast table and filling the dishwasher to fetching and serving drinks from the fridge. Mandatory for the successful execution of these tasks are exploration, interaction, cognition and perception capabilities of the demonstration platform ARMAR III apart from its technical design and the anthropomorphic hardware. In addition to these critical characteristics, which the robot needs to act reliably in an unknown and

dynamical environment autonomously, safety is crucial due to the close interaction with humans. This issue is not only important to prevent the human user from any harm, but also to ensure the correct execution of tasks without damaging the machine or the environment. Therefore techniques, comparable to the human reflex system, need to be developed to meet these concerns. The human-like limb movements and locomotion, including self stabilizing capabilities, will drive humanoids even further to the goal of broad acceptance in the public. To achieve this, biologically inspired movement generation is investigated, in contrast to classical approaches which generate robot movement by trajectory planning, zero moment point control and other techniques. This biological concept is based on the findings how muscle activation patterns are generated in the nervous system of mammals and how leg movement and locomotion in general is coordinated and adapted to external influences. The central pattern generator (CPG), a neural circuit in mammals, plays a key part in the generation of cyclic activation patterns and shows promise for the application in robotic locomotion control.

From the engineers point of view human robot interaction and human-like movement of robots are the most challenging tasks at present regarding the acceptance of humanoid robots in the society. These two challenges have to be accomplished to drive the acceptance of robots in society and everyday life further. Another issue in this context is, what expectations people have on humanoid robots and how these, influenced by movies and media, stay in opposition to actual technical achievements.

The paper of Ribeiro, Barata and Barreira referred that the use of pervasive networked devices is nowadays a reality in the service sector. It impacts almost all aspects of our daily lives although most times we are not aware of its influence. This is a fundamental characteristic of the concept of Ambient Intelligence (AmI). Ambient Intelligence aims to change the form of human-computer interaction, focusing on the user needs so they can interact in a more seamless way, with emphasis on greater user-friendliness. The idea of recognizing people and their context situation is not new and has been successfully applied, for instance, in the health and military sectors. However its appearance in the manufacturing industry has been elusive. Could the concept of AmI turn the current shop floor into a truly human centric environment enabling comprehensive reaction to human presence and action? In this presentation an AmI scenario is presented and detailed with applications in human's integrity and safety.

Following this paper, Gengenbach and Bretthauer stress the fact that accommodation is part of natures' gift of eyesight to each of us. It means that by changing the curvature of an elastic lens in the eye we can focus at objects at various distances. Unfortunately with increasing age this capability is being taken away from us again. While as a child we could focus at objects close to our nose, at an age of 60 the latest the "arms become too short" to hold the newspaper at the proper distance for comfortable reading. The reason for this is that with increasing age the lens loses its elasticity and thus its ability to alter its shape according to accommodation demand. The usual remedies are visual aids such as glasses or contact lenses.

At older age – continues the authors – the lens may lose its transparency leading to eye cataract. In order to avoid blindness the lens has to be removed

and replaced by an artificial intraocular lens (IOL). This is a standard surgical procedure taking about 15 minutes and a few hours later the patient can leave the hospital on his own feet with just a bandage over the eye. It is being performed about 2 Mio. times per year in Europe. Numerous attempts are under way to restore accommodation in this process, most prominent of all the implantation of so called "accommodative intraocular lenses". The most frequently implanted intraocular lenses are rigid and thus optimised for one object distance, usually far sight. Accommodative intraocular lenses claim to use the actuation of the ciliary muscle, which used to change the shape of the natural lens, to either change shape or position of the new artificial lens. This claim has so far not been proved conclusively. Also other approaches to restore accommodation based on ciliary muscle activity have not yet demonstrated their viability.

A new approach of these KIT researchers is to restore accommodation by means of an intelligent micro-system, which is being implanted as an "active intraocular lens". A fundamental requirement is that such a device can be implanted in the capsular bag by the same standard surgical procedures as a passive IOL. The micro-system must house all necessary functions to determine accommodation demand and change refraction in a range from 0 – 3 dioptres accordingly. Hence a sensor system for accommodation demand measurement, an active optical element, an energy supply and a controller have to be housed in a biocompatible way in a cylindrical volume of 10 mm diameter and 4 mm in length. This high degree of integration poses an interesting set of technical challenges that relate to ethical, social and economical questions:

- How can the implant be packaged in such a way that hermeticity and biocompatibility are ensured for an anticipated lifetime of 30 years?
- Can the pupil near reflex be used to measure accommodation demand and can the brain learn to actively control the pupil to accommodate?
- What are typical usage patterns of the eye and what do they mean for energy management of the implant?
- What are the consequences of failure of the implant and what are means to cope with it?
- Does the implant entail particular software related security issues?
- What do current trends in surgical technique mean for implant development?
- Does the implant have consequences for later medical treatments of its bearer?
- Is this an implant for everyone or just for certain social groups?

And finally, Compagna, Derpmann and Mauz (sociologists from Universität

Duisburg-Essen), said that the successful development of autonomous mobile-robot-assistants (RA) depends significantly on the well-balanced reconcilements of the technically possible and the socially desirable. Based on empirical research substantiated conclusions can be established for the suitability of "scenario-based design" for the successful development of RA and automated guided vehicle system (AGV) in an environment of stationary maintenance care facilities for seniors. Precise scenarios were developed and presented in this conference through extensive requirement analysis within a maintenance area, the specific needs developed by this investigation in alignment with the departments of re-search and development of RA and AGV. These scenarios are considered to be the background of further enhancements of the artifacts. With this the exchange of know-how between RA and AGV became possible. The connection of these - in other respects separated - development directions of autonomous mobile systems emerged as being very fertile and promising in the maintenance area for seniors.

From their point of view, the "scenario-based design" allows the processing of relevant knowledge about various target groups, in which an effective and functional exchange is possible: The scenarios are illustratively converted into sketches and display an image of the service narratively. This way weak points and difficulties of operational sequences and their technical translation are identified in early stages, even before the actual technical realization is initiated. Simultaneously, questions of occupational safety as well as legal aspects can be considered. A high acceptance can be achieved by clarifying criteria by the descriptiveness of the scenarios. Therefore, such processing also enables a cost effective development of innovative technologies in general. It is especially suitable for strongly interactive micro system technology e.g. the application of autonomous mobile systems in complex social systems.

The scenarios within an iterative process between relevant target groups are continuously adjusted until all involved parties consider the scenarios as being socially desirable *and* technically possible. The scenarios can be considered as a "boundary object" in which technical and societal innovation is efficient and coordination possible by bargaining the societal and technical factors through every party. This way, they provide themselves as a medium of an ideal participative technical development.

Based on the insertion of such scenarios RA and AGV are developed especially for the operation in a maintenance area. A pilot execution can be carried out in 2010. They will be examined and analyzed with usability tools specially developed for this area of application to continue further optimizing. Results in regards of advantages by scenario-based processing are already allowed to be ex-pressed. This does not only include the optimizing of the transfer of knowledge between developer and user, but also involves the exchange between developers of different platforms, like RA and AGV. Reasonable assumptions in regards of anticipated acceptance (e.g. by the maintenance management, nursing staff and seniors) can be distinguished on a foundation of request analysis, as well as on the iterative adjustments of the planned scenarios of the pilot execution.

An intensive debate was held before the lunchtime. After that it took place the continuation of working sessions with 3 presentations:

1. Tareq Syed: *„Mechanical animals" – the foundation of biomechanics, and its possible impact on a renewed understanding of mobile robots*, Institute of Philosophy, University of Karlsruhe
2. Mathias Gutmann: *Some fundamentals of robo-ethics: How autonomous are autonomous systems?*, Institute of Philosophy, University of Karlsruhe and ITAS-FZK
3. Michael Decker: *Technoid, humanoid, android? What should service robots look like?*, Institute of Philosophy, University of Karlsruhe and ITAS-FZK

Syed (KIT) paper mentioned that robots are commonly identified as technical imitations of different types of mobile animals (for example humanoid robots with erected trunks and bipedal walking mechanisms, or a variety of „animal-like" robots with more flattened or irregular body shapes, combined with diverse sets of appendages and different propulsion systems). Although some often cited classifications of mobile robots (i.e. the six-category classification of the Japanese Industrial Robot Association JIRA) do not necessarily fit this common sense view, there can be no doubt that at least a specific group of robot designers is interested in „natural paradigms" and biomechanical interpretations of organisms. In doing so, these designers will possibly use results and ideas from the research-field of the so-called „bionics". Typically, bionics are known for the direct transfer of „natural inventions" into the sphere of technical innovations. Thus, all robot-designs which are predominantly based on bionics or „natural paradigms" can be classified as mechanical organisms or, in case of mobile robots, as mechanical animals (due to the fact that animals can be defined as organisms which exhibit *mobility*, *motility*, or both types of movability).

Accordingly it seems that an important line of robot-designs is founded on *phenomena* which can simply be „discovered in nature". However, it is interesting to take a closer look at the works of those biologists which are interested in „organismic designs". This special line of thought was represented by some British invertebrate zoologists around the 1940/50ies, and in Germany in the 1960/70ies. Especially the latter researchers were aware of the fact that our understanding of „natural designs" is based on our knowledge of the technical history of humans. For example, the interpretation of invertebrate biomechanics is strictly based on human's knowledge of hydraulic principles.

By showing this for the main animal designs (reflected in a so-called „deep metazoan taxonomy"), one can show how animal body-plans are interpreted on the basis of technical paradigms. As a consequence, common descriptions of bionic constructions and mobile robots as „imitations of nature/organisms" become highly questionable, a conclusion which could change our understanding of at least some special types of mobile robots.

Gutmann (KIT) underlined that, if not being reduced to a branch of science-fiction literature, robo-ethics may be considered as a new hyphenated-

discipline comparable to medical-, bio- or gene-ethics. As such it marks the development and differentiation of research-programs as well as the increasingly accepted necessity of a philosophical reflection of ethical, legal and societal aspects in advance, i.e. even if the respective technologies are available only in nuce. This seems to be the case for the ethical reflection on robotics particularly by dealing with autonomous systems which may provide a considerable threat not only societal structures but particularly to the self-understanding of modern human beings. From this point of view the recent focus of robo-ethics on dealing with robots not as mere objects but as subjects of ethical considerations seems to underestimate the logical structure of normative ascription. The aim of the paper then is the reconstruction of ascriptive structures which allows us to achieve two goals at the same time, namely:

1. the introduction of the term „technical systems" as being derived from modelling-procedures of human action as if they were the task of technical systems and

2. the explication of the term „autonomous" with regard to technical systems that are supposed to support, enhance or even replace the original human action.

Based upon this reconstruction, it can be shown, that robo-ethics which assumes the respective technical systems (even if autonomous) as subjects of ethical reasoning to deal either with those systems in metaphoric way or commits a fallacy of category. The result we can state with Darwin (originally refusing the essentialist approach for the introduction of species): *„This may not be a cheering prospect, but we shall at least be freed from the vain search for the undiscovered and undiscoverable essence*" of ethical reasoning, which assumes autonomous technical systems as subjects of ethical procedures. At the same time we gain a broader perspective for a methodologically sound ethical assessment of the implementation and application of this kind of systems.

Finally, Decker (KIT) concluded in his presentation that the market for service robots is predicted to grow strongly in the next decades. The underlying assumption is that the market success of robots in technical manufacturing can be repeated for service applications. The crucial step is to free manufacturing robots from their "cages" and to make them smart and soft for interaction with humans. The guiding idea is the cooperation between humans and robots for cleaning, surveillance, entertainment, guidance etc. Since these applications can be described as ends humans want to achieve, the robot is becoming a means to these ends. In this means-end perspective the performance of the robot is assessable: A task can be performed in a good or a less than good way.

There is a general argument in the debate that humanoid robots are advantageous in performing service tasks, because their shape is optimized for environments humans live in. A robot with legs is able to climb stairs, the doors have a size optimized for an average human's size and a face-like arrangement of microphones as ears and cameras as eyes is helpful for the robot, because humans usually orient themselves to this "face" when talking to the robot, which makes it easier for the robot to recognize the person by

image processing and so on. The latter argument focuses on intuition of the human in the human –robot cooperation. Intuitively humans tend to look at a face, when they talk to somebody/thing. Intuitively people would know how to teach a certain task to the robot, for example an appropriate movement of the robot arm for cleaning. In this sense the human like shape of the robot makes it perform its tasks in a better way.

However there seems to be a limit to the human like appearance of robots. The so called uncanny valley (Mori et al.) describes that there is an increasing acceptance by humans of robots which become more and more humanoid. At a certain point this acceptance turns into rejection (when an android-like appearance is realized) and turns into the positive range again when the robot looks like a human. With reference to the above mentioned means-ends perspective on service robots this means that there might be an optimal human-like shape and appearance of the robot for a certain service task. And this appearance might be different for different fields of applications. Having the idea of a potential technology assessment project in mind, this contribution focuses on the research question "how humanoid should service robots be?". It takes into account different research results referring to the uncanny valley and combines it with currently published results from psychology, which describe the reactions of humans to more or less human like robots.

Debate preceded the presentation of concluding remarks and new topics for the sequence of the project in 2010.

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