ProRobot – Predicting the Future of Humanoid Robots

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Abstract. Humanoid robots are without question a hot topic in research today. But will they really be the next break-through invention that changes the face of the world, or are they just another over-hyped research toy? ProRobot is a study funded by the European Commission that will have a close look on the future of humanoid robots and their economic and social impact. The complete study will be published in summer 2003, and will especially concentrate on the prospects of research efforts and the differences of research activities throughout the world.

Keywords: Humanoid robots, study, roadmap, future predictions, socio-economic analysis

1 Introduction

The development of humanoid robots is in an interesting phase at the moment. The technological preconditions seem to be met, the first prototype developments look very promising, commercial interest is awakening. However, the future of humanoid robots is not clear, as it is not yet known if humanoid robots can manage the leap from the research stage to the general usage by non-researchers. There seem to be as many promising application fields as there are doubts about them. To help clarify the situation, the ProRobot study was set up. The study is funded by the European Commission, and will not only show the current state-of-the art of humanoid robot technology, but will give a full socio-economic analysis of this emerging area. The analysis will be based on a cost-benefit model comprising of five layers:

Social Benefit. What is the benefit to the end user? Measures the value of a new technology in terms of its usefulness to an end user or group of users in their everyday life.

Usability. What is needed to make the technology user-friendly? Measures the effort required by a user or group of users to be able to use a given technology.

Technical Viability. What technological opportunities make the project valid? Are new component technologies, infrastructures and methods available to implement the idea?

Feasibility. Can a production of the robots be assumed realistically? Are there obstacles or side-effects that make the technology too challenging?

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Exploitability. Can the product be sold? What is the market value and competition for the technology, product, or service. This depends upon the added value it offers to the user (i.e. social benefit) and the cost the user must make to acquire the benefit (i.e. usability).

In this way, predictions on the potential market size should be given, including predictions on the advance of all needed technologies. Significant technological barriers and socio-economic obstacles will be identified which may motivate specific R&D or support activities. As a conclusion, a road map will be given that shows all expected technological advances, research efforts and market developments.

The complete study will be published by the European commission in August 2003, and will be freely accessible to the public. As the study is under development right now, this paper can only give an overview about the related problems and tasks, while the detailed analysis and road-maps will be found in the study itself.

In this paper, we will give now a basic overview about the tasks and problems when predicting the future of humanoid robots.

2 So What Is Humanoid?

When talking about humanoid robots, the question will soon arise what can be called a humanoid robot, and what not. There is no widely accepted definition for a humanoid robot. For most developers it's enough if anybody can recognize a robot as humanoid just by looking at him. However, as the development of humanoid robots became more and more popular, there were soon machines where it was quite unclear if they still can be called 'humanoid robots'. All in all, there are two existent points of view: The first is to call a robot a 'humanoid robot' if he looks humanoid, which means that he has a structured body similar to a human being: An upright body with two legs (preferable with knee joints and the right proportions) and two arms, hands with five fingers and a head on top of all. The problem here is that even very cheap toy gadgets, that can hardly be called robots at all, meet this definition. Nevertheless this point of view is quite popular, because it's the most natural way for normal people to decide if a robot is humanoid. The other, more academic point of view is to define a robot as 'humanoid', if he can act like a human being. The emphasis here lays more on the possible actions of a robot, and less on his outer appearance and structure. If he can achieve typical 'humanoid' tasks in a normal 'humanoid' environment, he can be called humanoid, no matter how many arm joints he has or how many legs he uses. This point of view is not very satisfying, as some robots may achieve humanoid tasks without looking humanoid at all. Both approaches work together, if the robot needs the humanoid body to achieve the humanoid tasks. For moving in a normal house, for example, he needs to climb stairs and therefore needs legs instead of wheels. This is especially true if the robot must work in environments which are especially designed for the abilities of the human body. An example would be the driver seat in a standard automobile, where all arms and legs are needed in the right spot to allow the usage of the driving controls. The conclusion is that a robot that should act totally like a human must look totally like a human. He does not need however to copy the restrictions of the human body, so knees which bend in both directions might make him look a little bit non-humanoid, though.

What really brings together both points of view is the interaction with real humans. It is a widely accepted fact that a humanoid robot does not make much sense if he cannot interact with humans in one or the other way. For this task the humanoid appearance of the robot is without question beneficial. If a real human wants to work with a robot, or maybe just wants to play with the robot, he will feel much more confident if the robot is shaped in a friendly, humanoid form. He is more aware of what the robot can do, and what he cannot do, making the over-all work much easier.

In practice, most researchers and developers do not seem to care much about a clear definition for humanoid robots. Normally a collection of tasks is given, which should be fulfilled by the robot while using the structure of a humanoid body. Popular tasks and properties for such a humanoid robot are:

- Being a mobile robot with power supply and computer control on-board
- Navigating and moving in an environment made for humans
- Biped walking in a humanoid style
- Gripping and manipulating objects designed for humans
- Cooperative working with humans
- Interacting with humans without endangering their safety
- Having autonomous behavior
- Communicating with humans in a simple and intuitive way
- Using a stereo-vision system as main sensor system
- Using learning and adaptive behavior strategies
- Using human-like intelligence
- Having a design pleasing to real humans

While a complete humanoid robot should of course be able to show all of the above behavior, the technology at the moment is not advanced enough. Most humanoid projects are busy working on one or two of these tasks at the moment.

For the ProRobot study, we will examine all projects that intend to work on a humanoid robot, and work at least on two tasks of this list.

3 The Technological View

Not all technology for normal robots is essential for humanoid robots, and not all technology for humanoid robots is needed for normal robots. Based on the list of tasks that was given in the previous section, we can have a closer look on the different technology fields that are especially interesting when developing a humanoid robot. The progression of these technologies will greatly effect the performance of future humanoid robots, so a prediction of the future developments in this field is surely interesting.

Bipedal Walking Technologies: Often considered to be the core technology for a humanoid robot, there is not only the problem of mechanics, but also the sensorial problem of keeping the balance. True dynamic walking is still a challenge for every humanoid robot, but recent developments are looking quite promising, and good progress is expected in the future if the research interest is staying high. The research of bipedal walking is closely linked to the research on humanoid robots [1].

Navigation in Human Environments: This task should not be underestimated, as the natural environment of humans is quite complex. The robot must navigate with many dynamic objects (called humans) in his workspace while guarantee extreme safety to them. Most service robots face the same problems, and the development is still in a very basic level.

Gripping and Manipulation of Objects: For humanoid arms, the large technology knowledge of industrial manipulators can be used, so the arm development is considered to be a minor problem. However, humanoid shaped hands and gripping patterns are still under research, and working together with a humanoid sensor system is no trivial task. Many service robots deal with similar problems.

Communication with Humans in a Natural Way: Understanding and speaking in natural language is a complex task, but is already heavily researched by countless developers of computer systems needing a human-machine interface. Impressive progress has been made, and the commercial interest is rather high, so it seems as if solutions already on the market can be used for the humanoid robot.

Humanoid Vision and Senses: There seems to be no need to make the sensor system of a humanoid robot especially human-like, although stereo-vision systems are preferred by most development teams. Image processing is already a hot topic in research nowadays, so most times standard systems are used for the humanoid robots.

System Integration: This is the problem of putting all of the above technologies into a single, autonomous humanoid body while keeping the weight as low as possible. The robot must have good computational power, and must carry his own power supply with him. While computers are getting smaller and faster in regular steps, the power supply is still an unsolved problem. Batteries for supplying a very power consuming robot over a long period are very heavy, a problem well known from the development of service robots.

Depending on the intended tasks for the robot, some technologies might be more important than others. For RoboCup, the goal was formulated to have a team of humanoid robots playing against human opponents in the year 2050, which would certainly need good solutions for all technology fields above. Fig. 1 gives an overview about the state of the art today with help of a score card.

4 The Economic View

No prediction of future developments can be made without regarding the commercial interest in the desired technologies. The developers of humanoid robots are quite aware of the fact that these robots should be for sale one day, not only for a few scientists, but for a wide audience of normal people. So, while examining what the robot technology can achieve, we should also think about what the robot is intended to do. There are many different application fields for humanoid robots, from the more futuristic scenarios to the markets where robots are already for sale at the moment. In all application fields the main characteristic is that the robot must interact with real humans. Without any form of human interaction, a specialized robot will always have advantages over the humanoid robot.

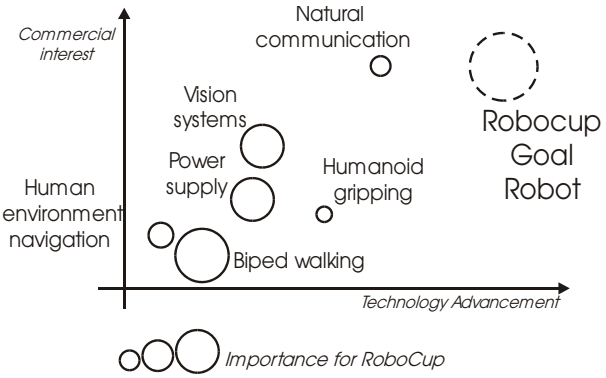

Fig. 1. An overview of the current state of the different technologies needed for a humanoid robot. Bubble sizes represent the importance of the technology for the goal of RoboCup. The RoboCup goal robot was put in there as a comparison, and was assumed to be of maximal commercial interest.

Possible fields of application are:

Industry: There are many robots working in the industrial production at the moment, but not humanoid ones. The reason is that the work is very specialized and repetitive, with human work force reduced to a minimum. The humanoid robot cannot profit from his greatest advantages, flexibility and human interaction. There are industrial fields where humanoid robots can be helpful because they can work close together with humans. The building industry is such a field, where a humanoid robot could act like a reliable co-worker, especially in unsafe environments. There are research groups that think of such an application field for their robot [2][3], but the goal seems to be very hard to reach. In addition, the cost efficiency of such work can be seriously doubted.

Military: Science fiction stories are full of super-human battle robots, which act as powerful, tireless and reliable soldiers. Chances are very high that these things remain completely fictional, as there are much better ways for robots to be used in the military. Even the U.S. military, which often favors high-sophisticated technologies, do not seem to think about this field of application. Corresponding to newspaper releases [4][5], however, they have raised a $50 million fund to research the usage of mechanized exoskeletons for human soldiers, and will share some of the problems with the developers of humanoid robots, e.g. a suitable power-supply. The U.S. defense research agency DARPA has also shown some interest in the development of autonomous, self-navigating robotic vehicles [6].

Service: This is perhaps the application field with the highest expectations for humanoid robots. Human interaction and flexibility are core characteristics of the service field, and the humanoid shape is certainly an advantage for any service robot, as the working environments doesn't need to be adjusted for such a robot. Especially working places with high personnel expenses, wide requirements and high cost pressures seem to be predestined for the usage of humanoid robots. An example is the health care field where many people are required to care for diseased, old or handicapped people. The usage of service robots seems to be not far away in the costly health care field [7].

Research: Most of the humanoid robots that are sold today are meant primarily for research purposes. While this is good for itself, it is mainly regarded as an intermediate step in the development of robots for other purposes. There are some research groups which develop robots very similar to real humans, and try in this way to learn more about the functionality of the human body and mind.

Entertainment: Last but not least, the entertainment sector is not one that should be underestimated, as its economic power might be greater than the service sector. For example, the retail figures of the latest U.S. census [8] show that over $62 billion have been spent on sporting and toy products, and $32 billion on consumer electronics like radio and television sets (not including computers), while only $10 billion have been spent on classic household appliances like refrigerators, dishwashers, vacuum cleaners and so on. Application fields for a humanoid robot in the entertainment sector seem to be unlimited, with high-sophisticated robots used as perfect toy companions. Many humanoids which are for sale today are meant primary as toys, while using impressive technology [9].

Advertisement: It might seem to be a little odd to mention the advertisement sector as an application field for humanoid robots, but in practice, many companies are raising high fundings for their humanoid robot projects mainly because of the reputation and prestige they gain with them. Humanoid robots are a good field to show the technological abilities of a company, and can get the interest of a big, world-wide audience including the media. The research community can certainly profit from these marketing issues. After all, it was also a question of prestige that brought man to moon and back.

The ProRobot study will carefully look at all of the above mentioned application fields and examine their future potential for humanoid robots. Commercial interest has always given a significant boost to the research activities, and so the future of humanoid robots will depend on how they can be used in an economically reasonable way.

5 The Social View

As mentioned in the previous section, the interaction with real human beings is one of the most important tasks for a humanoid robot. The question now is if real humans are willing to interact with a robot. The quality of cooperative work of humans and humanoids depend on the efforts by both sides, and service or entertainment robots are totally useless if people are afraid of them. Even assuming there is a perfect humanoid robot who can achieve all wanted tasks, the question remains if he is accepted by the people. How persons react on humanoid robots depends on a number of factors, some of them are shown below:

Local Society and Culture: People of different regions and nations react different on humanoid robots. It is well-known that people in Japan are quite enthusiastic about them, while people in Europe do not seem to care too much for them. The reasons for this might be based in the fundamental relationship of people towards new technology. The local differences might vanish when the new technology gets more common. After all, many new technologies are similarly popular throughout the world today.

Intended Audience: Humanoid robots are not intended to work solely with robotic specialists, researchers and academic persons. Instead, they should be able to interact with normal people who do not have any preconditional knowledge of robotics. Different audiences will react differently on a humanoid, though. It might be more difficult to establish a care robot in a home for old people than as a toy for children. It is therefore necessary to have a close look on the target audience before introducing a humanoid robot.

Safety Concerns: Absolute safety is a prerequisite for the successful introduction of humanoid robots in the human society. No human will work together with a humanoid robot if he must fear to be smashed by him. With every little safety concern the public opinion will drop noticeably. This is well-known from other technologies. Nuclear power and genetic engineering were once celebrated as wonderful technologies and are nowadays regarded with much more suspicion. There are even people who do not want to use a mobile phone because they fear the electromagnetic radiation. Robotic technology today is regarded as harmless for the most part, and great attention should be paid that it stays so.

Employment Concerns: To face the facts, robots have a slight reputation of stealing jobs. Much work once done by human workers is today accomplished by industrial robots. In most cases, this will presumably be not true for humanoid robots. They are hardly a solution for industrial work and make only sense when there are humans to interact with. However, there might be employees that seem to be replaceable by humanoid service robots. Anyhow, a long time will pass until humanoids are advanced enough (and cheap enough) to replace any human worker.

Movies and Literature: Humanoid robots are long time known from fictional stories and movies, and the image they got from this sources may influence the opinion of real humans about real humanoids. Chances are high, that the first thing a normal person on the street has in mind when he hears about 'Humanoid robots' is a Hollywood creation. For long times, robots were the bad boys of fictional stories, trying to enslave humanity for countless times. In the recent years, humanoid robots were used in a much more positive roles, and they act now mostly as comic relief ('Star Wars', Disney's 'Treasure Planet') or even as heroic sidekicks ('Star Trek'). It is good to see that a wide audience can accept a humanoid robot in this way.

Appearance: As the development of humanoid robots progresses, the question of the optical appearance and the design of the robot arises. Human users are strongly influenced by the look of the robot, and will react differently because of the emotions caused by its appearance. For example, a huge, 2-metres-sized robot will frighten many people, while they are quite comfortable with a child-sized robot with the same abilities. The realistic mimicking of the human appearance can be more frightening than a futuristic metallic look of the robot. It is therefore obvious that the role of design will increase when humanoid robots reach sale status.

6 Conclusion

This paper presented the scope of the ProRobot study. The study will concentrate on the predictions of technological advances, economic scenarios for humanoid robots

and social problems concerning these robots, as presented in this paper. These factors will be combined in a socio-economic analysis of the humanoid robot market. All potential markets will be discussed, but also potential obstacles and problems. A roadmap for future research activities will be given to act as a recommendation for research efforts. As the study is funded by the European Commission, a main point of interest will be the comparison of European efforts with other activities in the world. The study will be finished in the end of August 2003 and will be made available by the European Commission.

The content of the study as well as more resources for humanoid robots are presented on the web site of the ProRobot project, which is available under http://www.aboutrobotics.net.

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