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EDITORIAL
HUMANOID ROBOTS — HYPE OR HOPE?

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For a long time, many inventors have strived to create a perfect machine counterpart of humans — to copy the innards of creatures, but also with the objective to build "mechanical slaves" that to some extent relieve us from our burdens in everyday life. Humanoid robots — as an attempt to construct an approximation to human shape and behavior — can be considered as today's answers to these age-old dreams. In fact, they may be potentially very useful, not only as a research tool spanning many disciplines, but as everybody's personal "servant." Not yet fully realized but clearly conceivable are really autonomous robots that one can instruct to help at home or that can even do parts of our household chores unsupervised.

A little while ago this seemed to be pure science fiction, but recent developments justify a much more optimistic view. The first designs appeared in the early seventies, when the state of computing technology (but also sensors and vision, energy supply, etc.) was still far from what is needed for even a basic notion of "autonomy." Even though at that time one could not even dream of implementing higher-level cognitive abilities (vision, speech recognition, problem solving, planning, etc.) as integral functions of these bodies, there were impressive achievements in the emulation of human motor skills (walking, grasping, and even piano-playing).

Today, we observe a growing enthusiasm for the usefulness of humanoid research because the recent quantum leaps in enabling technologies let us assess more clearly what the potential benefits might be, i.e. direct applications but also spin-offs, made possible through these technological advances. Here are some of the possible applications areas, which we list regardless of the state of research today, as "controlled fiction":

Service: An autonomous humanoid robot can in principle use the same tools and appliances as humans and may hence become as flexible in adapting to new tasks as a human being. On the condition that it is close enough to the human shape and size, it may also operate in totally unaltered man-made environments. Moreover, if

it is capable of receiving its tasks by maintaining a dialogue with human instructors involving speech, gestures and facial expressions, then it will provide a functionality that surpasses by far anything that today's service robots have to offer.

Care: The increasing need for providing care to the elderly in modern ageing societies (particularly in Japan and Western Europe) calls for a solution that helps these people to lead a normal life in their homes for as long as possible. Clearly, a robot that is at their service at any time to offer flexible help, that comes in human shape, responds sensibly to its instructor's commands and is infinitely patient would be a real boon in this area.

Prosthetics: If we think of the humanoid robot as a collection of prostheses for limbs (but to some extent also for sensors), then it becomes clear that prosthetics and humanoid research may very fruitfully profit from each other. While there is still little evidence that "cyborgs" may ever be realized or the human mind be transferred to these machines, prostheses that afford some autonomy of their own may become an alternative to current designs, at least until it is possible to "re-grow" human organs.

Robotics Research: There is an infinite area for interdisciplinary research in mechatronics and materials science, computer science and systems integration, cognitive sciences including brain research, neuropsychology, linguistics and developmental psychology, and so on. Of particular interest is the use of the humanoid robot as a "test bed" for the simulation of the development of cognitive and motor skills on a real machine but also the integration of a machine that communicates in a variety of modalities with humans into our society.

Education: Students may *build* humanoids to learn in a practical exercise about their mechanical construction and the complex software modules that control it. In Japan this is already common practice. Students *use* humanoids to experiment with and enhance their skills. Here, too, the humanoid appearance may pave the way for robots to be used in sciences that have always refrained from using machines in their curricula.

Entertainment: Robots of human shape used for animation and advertisements at exhibitions and fun-fairs do not depend on a highly developed set of skills. To maintain a certain "surprise-factor" over time, however, it will be necessary to constantly improve their skills. Depending upon the target application, this may even include grasping and sophisticated navigation, e.g. for showing visitors around, manipulating and explaining the objects on display in a natural way. At the other end of the spectrum, small-sized humanoids may well play the role of toys for children that exhibit a greater wealth of behaviors and may hence be much more interesting for children to interact with than artificial animals. Fairly recently it has become clear that humanoids may well be an interesting complement to computer games by making them more "physical" and even more "real." Moreover, it would be

very interesting to have a humanoid robot complement a computer game, either as a complete embodiment solution or as a "physical avatar" controlled by a local computer (or, of course, by a remote human player — an attractive realization of telepresence and teleaction).

A number of enabling technologies has now reached a state of maturity that makes humanoid robots truely feasible: electrical motors are small enough, batteries are lightweight enough, and control computers and computer vision systems are powerful enough and knowledge is widespread enough to build small-sized to full-sized humanoids, a fact which has recently been demonstrated by a number of Japanese companies.

While it is highly speculative what the future will hold for these machines in terms of commercial success, important milestones have already been reached:

- A number of companies have developed professional humanoid robots that will hit the market in the near future, they say. Some of them are fragile, others are extremely robust, and, for example, can stand up on their own, and afford a number of interesting motor skills. It will be very important for the field as a whole that they soon become available as affordable research tools because only then will it be possible for a large community of researchers to develop solutions that, in turn, will make it attractive for additional researchers to become active in the field.
- Maybe even more important (at a second glance) is the fact that RoboCup.org have just finalized the rules for their "Humanoids League": three different classes of humanoid robots that will play soccer (and may be destined to beat the human world champions by the year 2050 — and as such in some sense the equivalent of chess-playing; this time, however, to beat humans' motor skills and dexterity). It is not difficult to predict that this will lead to an enormous increase in research activities worldwide because of the massive public interest researchers can attract by taking part in the RoboCup events, as was shown in the past — but also because it is fun.
- The IEEE Humanoids series of conferences, first organized at MIT in 2000, was established as a forum of exchange between researchers. It is attended by a much greater audience than was originally expected. Started as a bi-annual conference, there now seems to be enough publishable material to hold the conference on an annual basis. Recalling that, for example, the first IEEE conference on robotics and automation also began as a very small conference, one can be quite optimistic in terms of quantity and quality.

The last item is in some sense attested by this special issue of the *International Journal of Humanoid Robots*. The first six papers collected in this issue are elaborated versions of some of the papers presented at the 2003 IEEE conference on humanoid robots (Humanoids 2003). The September issue constituted the first of a two-part issue containing papers from that conference. The editors tried to group

the articles along the following lines: in the first issue (in September), we gave an overview of the technology of humanoid robots and their hardware/software implementation; in this second collection, we focus on interaction and, in particular, learning methods for use in humanoids.

We hope that these collections of articles give a suitable and enjoyable overview of the impressive accomplishments this promising field has already achieved.