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HUMANOID ROBOTS

Naga Nehanth
naganehanth.999@gmail.com

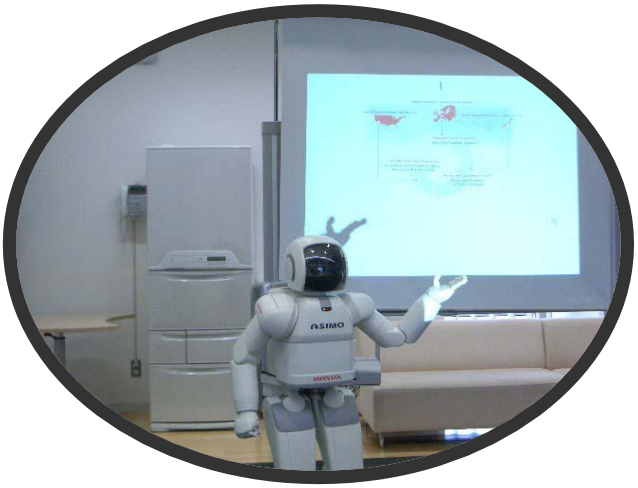
Surendra Rao
surendrarao1401@gmail.com

ABSTRACT

Humanoid robots have been fascinating people ever since the invention of robots. They are the embodiment of artificial intelligence. While in science fiction, human-like robots act autonomously in complex human-populated environments, in reality, the capabilities of humanoid robots are quite limited. This article reviews the history of humanoid robots, discusses the state-of-the-art and speculates about future developments in the field.

INTRODUCTION

Humanoid robots, robots with an anthropomorphic body plan and human-like senses, are enjoying increasing popularity as research tool. More and more groups worldwide work on issues like bipedal locomotion, dexterous manipulation, audio-visual perception, human-robot interaction, adaptive control, and learning, targeted for the application in humanoid robots. These efforts are motivated by the vision to create a new kind of tool: robots that work in close cooperation with humans in the same environment that we designed to suit our needs. While highly specialized industrial robots are successfully employed in industrial mass production, these new applications require a different approach: general purpose humanoid robots. The human body is well suited for acting in our everyday environments. Stairs, door handles, tools, and so on are designed to be used by humans. A robot with a human-like body can take advantage of these human-centered designs. The new applications will require social interaction between humans and robots. If a robot is able to analyze and synthesize speech, eye movements, mimics, gestures, and body language, it will be capable of intuitive communication with humans. Most of these modalities require a human-like body plan.



STATE-OF-THE-ART

Although, from the above, it may seem that the most important issues for construction and control of humanoid robots have been solved; this is not at all the case. The capabilities of current humanoid robots are rather limited, when compared to humans.

BIPEDAL LOCOMOTION

The distinctive feature of full-body humanoids is bipedal locomotion. Walking and running on two legs may seem simple, but humanoid robots still have serious difficulties with it. I see two opposing approaches to bipedal walking. The first-one is based on the zero-moment-point theory (ZMP). The ZMP is defined as the point on the ground about which the sum of the moments of all the active forces equals zero. Based on his ideas of passive dynamic walking, actuated machines have been built recently. These machines are able to walk on level ground. Because their actuators only support the inherent machine dynamics, they are very energy-efficient. They are easy to control, e.g. by relying on foot-contact sensors. However, because they use round feet, these machines cannot stand still. So far, these machines can also not start or stop walking and are not able to change speed or direction.

HUMAN-ROBOT INTERACTION

Many humanoid research projects focus on human-robot interaction. The general idea here is that the efficient techniques which evolved in our culture for human-human communication allow also for intuitive human-machine communication. This includes multiple modalities like speech, eye gaze, facial expressions, gestures with arms and hands, body language, etc. These modalities are easy to interpret by the human sensory system. Because we practice them since early childhood, face recognition, gesture interpretation, etc. seem to be hard wired in our brains. A smile from a robot does not need much explanation.

LEARNING AND ADAPTIVE BEHAVIOR

To be useful in everyday environments, humanoid robots must be able to adapt existing capabilities and need to cope with changes. They are also required to quickly learn new skills. Fortunately, humanoid robots have the unique possibility to learn from capable teachers, the humans in their environment. This is called imitation learning or programming by demonstration.

PROSPECTS

After four decades of research on humanoid robot impressive results have been obtained, but the real-world capabilities of humanoids are still limited. This should not discourage further research. In fact, research on

cognitive robots, including humanoids, is gaining momentum. More and more research groups worldwide are targeting this application. A good part of the difficulties humanoid robots face comes from perception. Here, more advanced methods are developed every year to cope with the ambiguities of sensory signals. The continuous improvements of computer vision and speech recognition systems will make it easier to use humanoid robots in unmodified environments. Advances are also to be expected from the mechanical side. Multiple research groups develop muscle like actuators with controllable stiffness. Such compliant actuation will significantly contribute to the safe operation of robots in the close vicinity of humans. Children are growing up now with robotic companions. As personal robots mature, they will meet prepared users.