Cost Oriented Humanoid Robots

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Abstract. Currently there are three categories of humanoid robots available: Professional humanoid robots developed by large companies with a huge amount of research resources. They are expensive and not available on the market. Research humanoid robots: The robots in this category are usually prototypes developed by scientists to implement and test new ideas. 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. Because of these facts in this paper a new fourth category – cost oriented humanoid robots (COHR) are introduced. 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.

Keywords. Humanoid robots, Cost oriented robots, Mechanical Design, Control concepts.

1 Introduction

It is an old dream to have a personal human-like robot able to help in everyday life. The main features of such a humanoid robot are bipedal walking , arms with gripping devices for manipulating, speech analysis and synthesis, facial expressions and gestures for communication. Walking machines or mechanisms are well known since some decades. Usually they have 4 to 6 legs (multiped) and nowadays 2 legs (biped) – walking on two legs is from the view point of control engineering is a very complex (nonlinear) stability problem. Biped walking machines equipped with external sensors are the basis for “humanoid” robots.

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 could work in environments which were until now reserved only for humans. Especially fixed and moved obstacles can be surmounted by legged robots. In addition to walking such robot could realize other movements like climbing, jumping…

2 Categories of Humanoid Robots

The humanoid robots available today can be assigned to three categories:

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Professional humanoid robots developed by large companies with a huge amount of research resources, both in turns of people and money. The idea is to develop robots that assist humans in tasks of their everyday life, serve for entertainment, leisure and hobby and can be “personal robots”. They are usually very expensive and are only partially available on the market.

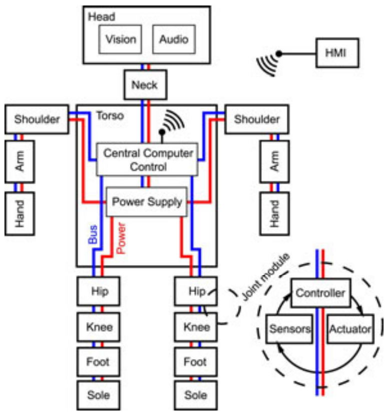

Fig. 1. Parts of a humanoid robot [1]

Classical examples are: the Honda robots (P1, P2, P3, ASIMO) – with the idea to assist humans in everyday working, the SONY robots (SDRX – 3,4,5,6 and QRIO) with the background to serve mostly for entertainment, leisure and hobby or in the future as personal robots.

Research Humanoid Robots: The robots in this category are usually prototypes developed by scientists to implement and test new ideas. These types of robots are very popular – approximate more than 1000 research labs work in this or related areas. Theoretical scientists from mechanical engineering implement walking mechanisms, control scientists implement new control strategies, computer scientists implement new ideas in AI and computer vision, social scientists implement human machine interfaces (HMI) for efficient communication between humans and robots. Usually these robots have a very poor mechanical design and a “closed” software.

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.

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, in this contribution a new fourth category – ***Cost Oriented Humanoid Robots (COHR),*** will be introduced. These robots will be able to support humans in everyday life like 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, ... [2]

3 State of the Art

A COHR can be conceived by using industrial components with a robust simple mechanical design, easy operation through flexible programming. The use of such components may decrease the complexity of design. Therefore, low-cost components are a very good expedient for reducing the cost and time of designing humanoid robots. Nevertheless, such a low-cost design will yield to a humanoid robot with limited capability both in mechanical versatility and programming flexibility. But in general, it can be thought that a low-cost humanoid robot can have still interesting performances for mobility, manipulation, and autonomous operation that are useful in many applications. Some examples are:

In [3] a low-cost easy-operation humanoid robot CALUMA is described. In this humanoid robot each subsystem must be operated as a part of a whole structure, rather then as a individual prototype. The proposed subsystems for CALUMA structure have presented operation problems as consequence of their application as a part of a humanoid platform.

The Robo Erectus [4] aims to develop a low-cost humanoid platform so that educators and students are able to build humanoid robots quickly and cheaply, and to control the robots easily. Currently works are ongoing to further develop this platform for educational robots, service robots and entertainment robots.

Other robots of this category are described in [5], [6],……..

4 Cost Oriented Design

The cost oriented humanoid robots presented before are more or less (“advanced”) toy robots. Therefore in the following first ideas for the development of a real robot able to support humans in everyday life as well as for industrial applications will be presented based on our experiences from mobile robots realized in the past [7], [1], [8], [9].

4.1 Mechanical Construction [10]

First of all the construction should be reasonable lightweight for power saving and increasing the operation time of the robot. Existing robots with extremely lightweight constructions are not able to handle the necessary payloads for the tasks mentioned before.

Cost orientation can be reached by

- Using commercially available components for a reasonable price
- Using standardized modules available on the market or to be developed

For design there are, according to our experiences, some new ideas necessary. Some of these will be presented in the following using our “Teen sized” humanoid robot “Archie”.

4.1.1 Standardized Joints

For our humanoid robot Archie we developed a joint module which can be used as a standard for all joints on the robot. One design goal was to copy as close as possible the physical appearance of a human. This requires a high volume to power ratio; high torque in a small volume. This can only be reached with harmonic drives. Therefore the joints of Archie are realised by brushless motors coupled with a harmonic drive, which gives the robot very high performance and efficiency. Each of these joints (modules) realise only one DOF. Because of the modular design they can be combined to joints with two (e.g. shoulder) or three (e.g. hip) DOF`s.

4.1.2 Hip Design

For the hips moving the upper body, tooth belt drives were used. The main disadvantage is the backlash resulting from the elongation of the belts because of the high tension and the backlash of the tooth wheels. A suitable solution of the problem is the usage of tighteners.

4.1.3 Legs

For the legs the standard joints – 9 for each are used mounted on aluminum profiles. To minimize the torsion additional cross ties on the thigh and the shank, similar to a framework construction are attached. The additional weight is a minimum and the additional parts are easy to integrate.

4.1.4 Torso

Because of the limited space for the electronics in the upper body it`s included in the torso. The circuit board with the controller and the peripheral devices will be mounted directly in the front of the upper body. This yields to more space for the motion controllers which can be arranged freely in the space for the motor of the head. An additional advantage is that the centre of mass is now nearer to the hip.

4.1.5 Arms

To fulfill the described tasks the robot has to have two arms with the necessary DOF`s. As mentioned above the layout should be the same than the legs. As the arms are shorter and get less loaded the torsion should be less a problem than at the legs. Additionally a minor deformation of the arms would not have major effects as the arms are not important for a smooth movement of the robot. Additional to the rotation two drives are combined to the shoulder and thus provide the same amount of DOFs as the human shoulder. The forearm is again connected with a drive which provides the one DOF of the elbow. The rotation of the forearm a human being is capable will be realized with an additional joint in the hand.

4.1.6 Head

The head needs a proper mounting system for two cameras, the eyes of the robot. The pictures of the cameras will be computed by a stereo vision system that makes the robot able to move through unknown surrounding. A human being is partially able to move the eyes independent to each other. This possibility will not be realized since the stereo vision systems needs one direction recorded from two different viewing points. Thus a simultaneous movement of the cameras is fundamental.

4.2 Control

The suggested control system is based on a distributed architecture. In this structure, each joint is controlled individually by a motion controller which in turn communicates with the central controller via a data network. The central controller is responsible for the following tasks:

- Energy management
- Multitask management
- System failure detection
- Performing received commands
- Synchronizing the joint controllers
- Ensure the overall balance of the robot
- Calculating the location of the supporting polygon
- Preventing mechanical collision in manual movements
- Updating the desired positions resulted from calculation with the joints
- Splitting general commands into joint commands (for combinational movements)

A method able to minimize these unexpected effects is based on the relations between forces and moments which appear in different regions of the robot. The attempt to control the moment of robot joint with respect to a reference point is a solution hereto problem. The angular moment of human in time of walk, with respect to an outside reference point, from the actual studies, has a variation nice and a slow, and in stationary state actually 0. This was the reason for beginning the research and the implementation of a method where exactly this is attempted: the check of the angular moment of robot.

The control system is realized by a network of processing nodes (distributed system), each for one node, consisting of relative simple and cheap microcontrollers with the necessary interface elements. According to the currently available technologies the main CPU is a module, one processor for image processing and audio control and one microcontroller for each structural component. To increase the processing power of the entire network additional nodes can be easily added to the network. Special nodes are reserved for vision processing, sound synthesis and speech recognition as well as for sensor processing.

4.3 Cloud Robots [11]

The idea of robots that rely on cloud-computing infrastructure to access vast amounts of processing power and data is not very new. This approach, which some are calling "cloud robotics," would allow robots to offload compute-intensive tasks like image processing and voice recognition and even download new skills instantly, For conventional robots, every task—moving a foot, grasping an object, recognizing a face—requires a significant amount of processing and pre-programmed information. As a result, sophisticated systems like humanoid robots need to carry powerful computers and large batteries to power them. Cloud-enabled robots could offload CPU-heavy tasks to remote servers, relying on smaller and less power-hungry onboard computers. Using the cloud, a robot could improve capabilities such as speech recognition, language translation, path planning, and 3D mapping.

But cloud robotics is not limited to smart-phone robots. It could apply to any kind of robot, large or small, humanoid or not. Eventually, some of these robots could become more standardized, or de facto standards, and sharing applications would be easier.

5 Conclusions

Service-robots will become a real "partner" of humans in the nearest future. One dream of the scientists is the "personal" robot. In 5, 10 or 15 years everybody should have at least one of such a robot. Because the term personal robot is derived from personal computer the prices should be equal. Some new ideas in automation especially in robotics are realized very fast while others disappears [1].

The cost oriented humanoid robots presented in chapter 2 are more or less ("advanced") toy robots. Therefore in this paper first ideas for the development of a real robot able to support humans in everyday life as well as for industrial applications are presented based on our experiences from mobile robots realized in the past.

To support humans in everyday life e.g working place, household, ... , these cost oriented 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. Another contribution to COHR could be the philosophy of "Cloud Robots".

Probably COHR are a first step to one of the oldest dreams of the humans – the Personal Robot.

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