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Cost Oriented (humanoid) robots

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Abstract: Cost oriented (humanoid) robots – CO(H)R - were introduced in 2011. 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.

Based on previous works in this paper a new control concept and a new "CO gear" will be presented. If we will have in the future CO(H)R the old dream of the robotics community "personal" robots is realized. In each home there will be at least one. Finally open questions like "human – robot" interaction, robo-ethics,….. will be shortly outlined.

Keywords:Robots,Drives,Control,Ethics**.**

1.INTRODUCTION

Humanoid robots are on the way to be used more and more in industry especially in the intelligent production like agile manufacturing, cyberphysical systems nowadays called "Production 4.0". Currently there are nearly no CO(H) robots available for such applications. One of the main barriers is the price and the availability of such robots. Therefore "Cost Oriented (Humanoid) Robots – CO(H)R" are necessary in the nearest future for such applications.

There are a lot of publications dealing with this subject available in the literature mostly from authors with an nontechnical or IT background. Only few of them describe this problem from the viewpoint of robotics and control engineering and presents only simulation results.

One of the differences to most of the publications mentioned above is the availability of a real cost oriented humanoid robot (COHR) named Archie, developed at IHRT in the last years for testing theoretical results on a real system. According to the philosophy "cost oriented" most of the parts are available on the market for reasonable prices (Kopacek, 2011).

Archie is in development with the goal is to build a cost oriented humanoid robot supporting humans in everyday life. Therefore Archie has the size of an European male teenager and has a head, a torso, two arms, two hands and two legs. The robot should be able to walk in an unknown environment, to do some work and to express feelings depending on the situative context. The human capability is not a simple movement and this is the reason why Archie is a good test object for developing and evaluating some walking methods, e.g.: the Zero Moment Point-Method (ZMP).

Details of this robot are available e.g.(Schörghuber, Kopacek, 2014). The results can be easy transferred to other humanoid robots.

2. ROBOT JOINTS

2.1 State of the art

Humans have muscles to actuate one to three joints degrees of freedom – DOF`s of one joint . Trying to copy a human muscle, the robot's joints need to fulfill the following requirements:

- High torque,
- Ability to operate in a wide velocity range,
- Small size,
- Light weight,

Currently there are no appropriate artificial muscles available. Probably by means of nano- and femtotechnology such drives will be available in the nearest future.

Currently all of the 13 joints in the robot's structure are actuated either by a brushed or brushless DC-motor and are controlled by a commercial micro-controller using the standard three-cascaded control architecture for the current, velocity and position control. The overall stability of the robot depends above all on the accurate performance of the position and velocity commands sent to each joint. For, the dynamic behavior of the joints consisting of a DC-motor and a gear set is investigated in detail in Kopacek et.al (2014).

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2.2 Harmonic drives

In our case most of the joints are currently actuated by a brushless DC-motor with a "Harmonic Drive" gear, the remaining are actuated by a brushed DC-motor using a belt drive.

A brushless DC-motor offers various advantages compared to a brushed DC-motor, such as a smaller motor size, higher efficiency, less weight, less maintenance, longer life time and a good torque-to-rotational-speed characteristic.
The used brushless industrial DC-motor has the specifications listed in Table 1.

Table 1. Maxon E 45 flat (Schörghuber, Kopacek, 2014).

Power	50 [W]
Nominal voltage	24 [V]
Max. continuous torque	82.7 [mNm]
Max. peak torque	822 [mNm]
Max. continuous current	2.32 [A]
Max. peak current	23.3 [A]
Max. rotational speed	10000 [min^{-1}]
Number of pole pairs	8
Number of phases	3
Weight	110 [g]

For the exact determination of the actual position of the rotor, each brushless DC-motor is equipped with three Hall sensors. To operate the brushless DC-motor in the robot joints an industrial digital micro-controller (Schörghuber, Kopacek, 2014).was chosen. This micro-controller reflects a standardized commercial device that can be applied in various industrial applications, such as robots or other complex machines with a three-cascaded digital control architecture to control the current, velocity and position of the brushless DC-motor.

2.3 Cyclo Drives

Currently in humanoid (articulated) robots “Harmonic Drives” or commercially available “Cyclo Drives” are used Each of these systems has advantages and disadvantages. Concerning COHR both need for production high precision parts produced in special, very expensive machines. This yields to high production costs and consequently to high selling prices. There are also “Planetary gears” available but they are usually to heavy for this application.

Therefore in the following an alternative COHR solution with similar performance in terms of: transmission ratios up to 200: 1 in one stage, weight, volume and backlash will be presented. It is a new drive based on a totally new concept avoiding the disadvantages mentioned before. It works entirely by rolling and has a set of internal regulations that reduce the backlash and allows manufacture all components in conventional CNC machines. Therefore the production costs are reduced dramatically**.**

This new construction based on a different mechanism described below consisting of 4 main parts:

A planetary gear reduction
An eccentric regulator for the gear.
A module for eccentric motion transformation (geared down-reduction) in a concentric movement collinear with the output shaft.
Regulation system to eliminate internal games-clearance

The geometry of the parts offers the possibility to manufacture these on machine tools with low precision.
The whole assembly is complemented by standard bearings, which are mounted as adjustable parts. Not only allow rolling reduction ratio scheme and also admits remove global units games of part interaction at armed stage (Fig.1)

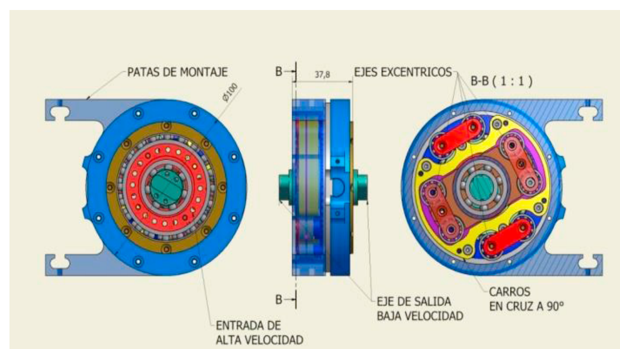

Fig.1 The cyclo drive

Planetary gear reduction
It comprises a pair of classic gear, one toothing meshing with another external gear. The number of teethes of the internal toothing and the difference between the two gears, determine the overall transmission ratio.

Eccentric regulator for the gear
By two pieces with identical eccentricity (Fig. 2) the relative angle between each piece allows to regulate the distance between the axes of the two gears piece, from collinear (when the 2 eccentricities offset) to a maximum (when the two eccentricities are added) The theoretical wheelbase gear is intermediate value between the two limits described. With this regulation, it is possible to find a solution that enables optimum gear, minimizing backlash between the two parts in contact. A set of holes and threads angularly offset from one another, for fixing the position once regulated the position of the pieces of regulation of eccentricity