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Humanoid soccer robot

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Development of a humanoid robot for soccer competition

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This article discusses the progress in design and construction of a soccer playing humanoid robot. This robot has been used in the Humanoid RoboCup competition in Suzhou, China in juli 2008.

Introduction

Two years ago the three technical universities in the Netherlands joined forces to start a 3TU wide initiative: participating in the Humanoid League of RoboCup.

Research groups at the three universities of technology in the Netherlands, have agreed to join efforts in creating a humanoid robot able to participate in the RoboCup contests.

The 3TU team has been named 'Dutch Robotics' [2], and its first goal is to build robots that compete in RoboCup Soccer competion. The first competion to participate in was held this summer, in Suzhou, China. In the coming years, the team will be further developing these robots, and will try to win the TeenSize Humanoid League of Robocup 2009 in Graz, Austria.

In the Humanoid league, robots with human-like bodies and human-like sensing compete. Each year, the Robocup organisation changes the rules to make it closer to a real soccer game, and the teams face more complex design requirements, and build more advanced robots.

By taking up challenges such as Robocup Soccer the team will develop techniques to enhance the vision, lightweight design, actuation control and the intelligence of humanoid robots.

Fig. 1: 'TUlip' humanoid soccer robot

RoboCup

RoboCup [3] is an international robotics competition founded in 1993. The aim is to develop autonomous robots with the intention of promoting research and education in the field of artificial intelligence.

RoboCup chose to use soccer game as a central topic of research, aiming at innovations to be applied for socially significant problems and industries. Soccer has many aspects that next generation technologies need to embrace. For example, team work, real-time perception and decision, and high-level of motion control.

The official goal of Robocup is:

By the year 2050, develop a team of fully autonomous humanoid robots that can win against the human world soccer champion team.

Leagues

RoboCup is devided into several leagues. The most famous are the wheeled platforms. For instance the MI20 team from Information Science competes in the small size league (of FIRA, a different Robot competition). In the Robocup there are two wheeled-based leagues: small size and mid-size. The Dutch team from Eindhoven participates every year in the mid size league (and reached the finals this year) There is also a simulation league, in which the focus lies on soccer strategy and simulated teamplay. There is a swimming robot league, a childrens's league, specials on search and rescue and domestic robots, and finally two humanoid soccer leagues: kid-size and teen-size. In the kid-size league, control of a robot is not a major challenge anymore: you can get very far with a relatively simple construction made with small servo's, without balancing control. Almost every team uses a construction made with servo's by Robotis. They are in a way similar to RC-servo's which are used in model cars and such. In the teen-size league it is still a challenge to stand upright and to walk.

Team Dutch Robotics competes in the RobocupSoccer Teensize Humanoid league. In this Humanoid League, autonomous robots of over 1 meter, with a human-like body plan and human-like sensors play soccer against each other. The robots also have to compete in several Technical Challenges: the robots will walk trough an obstacle course, will be dribbling around poles and have to cross the soccer field as fast as possible.

Dynamic walking, running, kicking the ball while maintaining balance, visual perception of the ball, self-localization, team play are among the many research issues investigated in the Humanoid League.

Event

This year the event was organized in Suzhou, a large industrial city in the Eastern part of China, roughly 100 km west of Shanghai. With a large team consisting of seventeen students and researchers from Delft Univeristy and two from the CE group of the University of Twente, an entire lab plus two robots were shipped to China in order to participate in the competition. Although the robots did not manage to participate fully (they could stand still and track a ball, but for example penalty kicking or walking were not implemented yet), it was a very useful experience. It also was a great way for improving cooperation between the teammembers, and it spurred the development process, the trip and deadlines being great motivators. Before shipment to China the robots were not even fully operational, so a lot of work had to be done on site. In the final days of the competition both of the robots were completely operational (so all joints could be controlled, sensors could be read) and both of the robots could stand upright (which might not seem a big achievement, but given the circumstances, it was!)

The robot

The main challenges in the development of humanoid robots are:

- Control of a large number of degrees of freedom
- Interaction with complex and dynamic environments
- Safety issues in environments in which people are present
- Handling a large number of different tasks

Fig. 2: Work in the 'pits'

Added to these main challenges in the research field are the RoboCup soccer rules, which change from year to year, and our own research goals, such as energy efficiency in robots.

Passive Dynamic Walking

The design of the robot is embedded in research on energy efficient walking. Ideas to use especially the 'natural' dynamics of a mechanical system for walking originate from the ideas from Tad McGeer [5] on Passive Dynamic walking. Both in Delft [7] and in Twente [8] robots have been build that are dubbed 'Powered Passive Dynamic Walkers'. The contradiction in this term lies in the fact that although the dynamics of the system are chosen, such that the passive system could be

Fig. 3: The Dutch Robotics RoboCup 2008 team

able to perform a walking cycle, actuation is added in order to maintain this walking cycle, or to increase stability. For example the robot 'Dribbel' [8] that has been build at the CE group at University of Twente walks without actuated (so passive) knees, but uses a DC motor in the hip to power its (partially passive) walking motion.

Design

The mechanical design of the robot is entirely done in SolidWorks by Mechanical Engineering students at the TU Delft [1]. The design process was started in early 2007, based on the experiences with Delft's robots Denise, Meta and the latest Passive Dynamic Walker by Daan Hobbelen: Flame [7]. The parts for the TUlip robot were ready in Oktober 2007, after which the difficult process of assembly started. Four robots have been built for every participant in the team, so there is a robot in Delft, one at the TU/e, one at Philips and one in the CE lab in Twente. Every team has asselbled its own robot in order to gain as much 'inside' knowlegde on the mechanics as possible at every robot's 'home'.

The current model is 1.2 meter high and weighs 20 kG. The robot uses 14 geared 60 Watt DC motors by Maxon. Interesting point is that, just with the passive knees in Dribbel, not all degrees of freedom are actuated. In sideways direction the ankle joints use springs to keep it in place (see figure 5)

Control

The robot is controlled by a Poseidon Single board computer with Via chipset, operating at 1 GHz. For position feedback high-precision (30000 counts per revolution) incremental encoders are being used on every joint. The control hardware is summarized in table I.

Table I: Tulip's control system

Computer	1 GHz Diamond Systems Poseidon board, 512 MB RAM
Operating system	Linux + Xenomai
I/O cards	Mesa Electronics 4I65 I/O card (2x)
Inertial sensor	XSens MTi
Joint encoder	Scancon 2RMHF 30000 counts/rev
Motor encoder	Agilent 2000 counts/rev
Vision	Custom, under development
Foot sensor	Tekscan Flexiforce load cell + accelerometer
Motor	Maxon RE 30, RE 25 in arms
Amplier	Elmo Whistle 3.5 A RMS
Electr. battery	Kokam 3 cell 6 Ah LiPo
Motor battery	Kokam 8 cell 26.4 Ah LiPo
User input	Matrix Orbital LK204-25 LCD

Fig. 4: TUlip in action against team Osaka

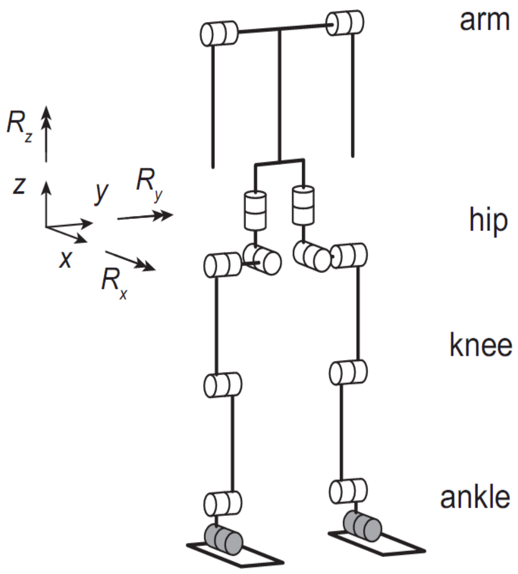

Fig. 5: Degrees of freedom in 'TUlip'

Series elastic Actuator

Four joints are controlled using the so called series-elastic principle. The motor is not connected directly to the joint axle, but is connected with bowden cables with deliberately placed extra compliance. This is a method to control the output torque on a joint specifically. The deformation of the series-elasticity is a measure of the applied force. This type of actuation was brought under attention first by Gill Pratt, MIT in the early 90's [6]. The idea of using series elasticity combined with a tendon drive, as being used in the robot's legs (see figure 6) has also been used in for example the Lopes powered walking machine at BME [9]. Besides allowing torque sensing at the load side, a series-elasticity can also be used to store energy on impact (for example when the robot foot hits the floor). Various projects [10] aim for re-use of this energy.

This method simplifies the implementation of a torque controller, but makes the mechanical design more complex, since two positions per joint need to be known (see figure 7) The motor position is measured using an incremental encoder mounted on the motor output shaft (before the gearbox, so the resolution can be smaller), the position of the end effector is measured using the aforesaid high-resolution encoders (see table I).

The contribution on the project from Twente partially on the electronics design, but focusses mainly on simulation. The electronics in the foot were designed by Master- and Bachelorstudents at CE. The foot sensor system consists of a PCB containing four pressure sensors and an acceleromter, operating as the first Plug-And-Play foot sensor system ever (it connects to USB as a standard HID). A lot of effort has been put into making a reliable 20-sim model (see figure 8) in order to develop controllers and walking algorithms for the robot. At the moment this simulation model is able to stand up, the work is continued on getting a reliable and robust walking algorithm.

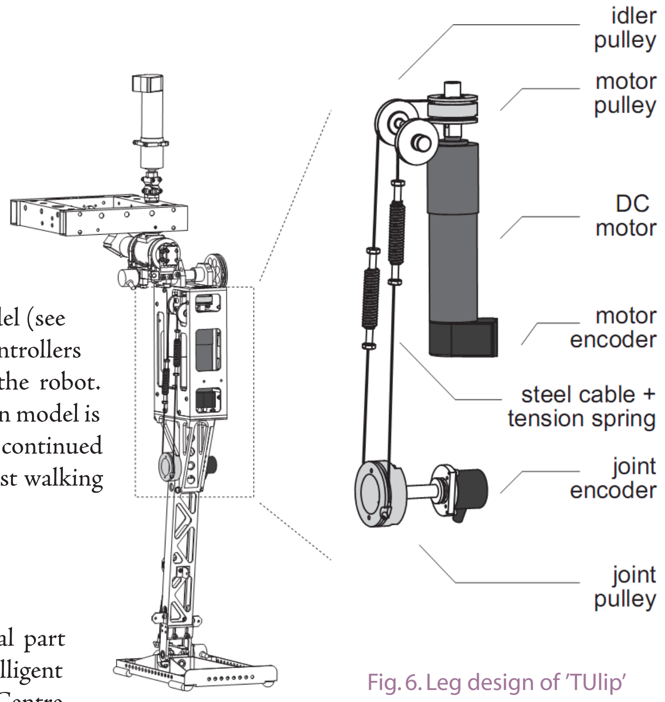

Fig. 6. Leg design of 'TUlip'

Organization

3TU

This initiative is an integral part of the 3TU Centre for Intelligent Mechatronic Systems. This Centre was founded in February 2007 by 3TU, the federation of the three universities of technology in the Netherlands.

The Dutch Robotics project is part of a long term vision shared by the three Dutch universities and the Dutch industry for the development of a new generation of robots. While robots have been working in controlled environments in factories for more than fifty years, this new generation of robots will become affordable and sufficiently autonomous for use in households. The market for domestic robots is expanding slowly, and 3TU is on the forefront of developing this technology in the Netherlands.

Team roles

Dutch Robotics is a cooperation of different research groups at the three Dutch universities of technology. These groups have different fields of expertise that are required in the development of intelligent humanoid robots.

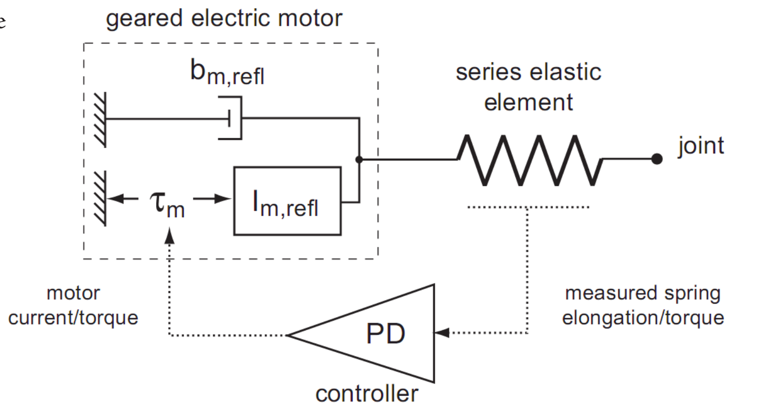

Fig. 7.: Control of the series elastic joint

- Advanced Control (Prof.dr.ir. Stefano Stramigioli, University of Twente)
- Embedded Systems (Prof. dr. Nijmeijer and prof. dr. ir. Steinbuch, Eindhoven University of Technology)
- Robot Vision (prof. dr. ir. Jonker, Delft University of Technology and ir. T.P.H. Warmerdam, Philips Applied Technologies)
- Biorobotics (prof. dr. Van der Helm and dr. ir. M. Wisse, Delft University of Technology)

Future

Next competition is being held in 2009 in Austria. Our team at the UT can seriously use reinforcements from practically skilled students from electrical- mechanical and software engineering. If you are interested, please get in touch with dr. Raffaella Carloni (r.carloni@utwente.nl).

Acknowledgments

This project is being realised as collaborative effort of Delft Technical University, Eindhoven Technical University, University of Twente and Philips. In Twente the project is hosted at the Control Engineering Group (EWI). Work on the robot is done by Phd students G. van Oort and E. Dertien and master/bachelor students P. Daemen (modeling), C. Doggen (foot electronics), W. Bouwman (modeling and simulation) B. Peerdeman (vision based world modeling), E. Dalhuisen (learning walking control), E. Ricci (foot calibration) under supervision of R. Carloni and prof. S. Stramigioli.

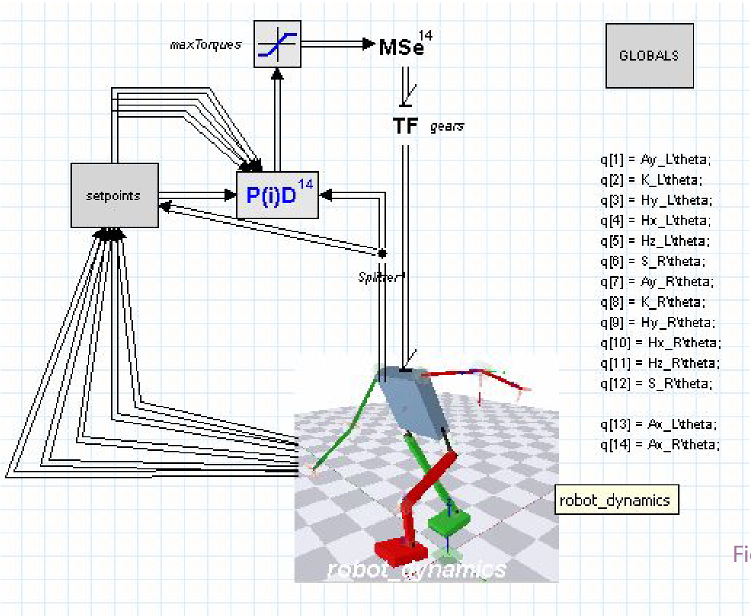

Fig. 8: 20sim simulation of 'TUlip'

References

[1] D. Hobbelen, T. de Boer and M. Wisse, *System overview of bipedal robots Flame and TUlip: tailor-made for Limit Cycle Walking*, 2008 IEEE/RSJ International Conference on Intelligent Robots and Systems, Nice, France, Sept, 22-26, 2008

[2] Project website: http://site.dutchrobocup.com/

[3] RoboCup website: http://www.robocup.org

[4] Robotis website: http://www.robotis.com

[5] T. McGeer. Passive Dynamic Walking. The International Journal of Robotics Research, 9(2):62–82, 1990.

[6] G. A. Pratt and M. M. Williamson, *Series elastic actuators*, IEEE International Conference on IntelligentRobots and Systems, vol. 1, pp. 399 - 406, 1995.

[7] D. G. E. Hobbelen and M. Wisse. *Limit Cycle Walking*, In M. Hackel, editor, Humanoid Robots, Human-like Machines, book chapter 14. I-Tech Education and Publishing, 2007.

[8] E. Dertien *Dynamic walking with Dribbel*, Robotics and Automation Magazine, IEEE Volume 13, Issue 3, Sept. 2006 Page(s):118 - 122

[9] J. F. Veneman, R. Ekkelenkamp, R. Kruidhof, F. C. T van der Helm and H. A. van der Kooij. *A Series Elastic- and Bowden-Cable-Based Actuation System for Use as Torque Actuator in Exoskeleton-Type Robots*, The International Journal of Robotics Research 25:261-281 2006.

[10] S. Stramigioli, G. van Oort and E. Dertien. *A concept for a new Energy Efficient actuator*, AIM 2008. 2-5 July 2008 Page(s):671 - 675