Team Description Paper HWM (Humanoid Walking Machine)

Philipp Senn, Benjamin Steinwender, Wolfgang Stocker, Wolfgang Werth, Markus Zauner, Peter Zupan

Carinthia University of Applied Sciences, Europastrasse 4, 9524 Villach, Austria
E-Mail: `w.werth@fh-kaernten.at`
Web: `www.fh-kaernten.at/hwm`

Abstract. *Abstract* – In this paper an autonomous humanoid robot is presented designed for participation of the RoboCup Humanoid Competition 2009. The robot was originally developed in 2005 and redesigned since 2007 by two teams of students in the course of a 2-semester project work. The robot is based on distributed system architecture, consisting of a Single Board Computer and several microcontroller-units. Multiple sensors provide feedback information about the robot's state and perceive the environment. Twelve DC motors with gear boxes are used to actuate the joints of the robot. The robot is able to balance on one leg and to walk in a stable manner on flat and hard underground. Furthermore it can locate a ball using a moving head together with a vision unit and of course kick a ball.

1 Introduction

Building and controlling a humanoid robot sets high demands on mechanical and electronic system architecture. Fascinated by this complex and challenging problem, a research group consisting of several student groups and staff members was founded to build a functioning humanoid robot. The project was realized in the context of education at the Carinthia University of Applied Sciences. The most desired project goal was to implement a stable human-like walk. In addition, the robot should meet the demands of the RoboCup challenge. This resulted in the participation in the RoboCup competition (Atlanta 2007).

2 Mechanical Structure

The robot is supposed to be preferably human-like, thus the robot's legs are based on human legs. Each leg has 6 degrees of freedom (DOF). In addition two more motors control the movement of the head, hence the robot possesses 14 DOF altogether. DC motors with gear boxes and tooth belts are used to actuate the joints. The mechanical structure of the legs was made in cooperation with another university, while the electronic part of the robot was designed and constructed by the project teams.

3 System Architecture

The system is based on a distributed architecture. Fig. 3 shows the most important system-components of the robot.

A Single Board Computer (SBC) is used as central processing unit. This SBC uses INtime as real time operating system and provides a reliable base for the execution of the Locomotion and Balance Control.

The SBC communicates via high-speed serial bus interface with several sensors and actuators of the robot.

The modified RS485 - bus operates at a baud rate of 1.152Mbps and uses differential signaling. The SBC acts as single master and addresses slaves using an efficient, proprietary protocol. Due to the distributed system architecture, it is easy to expand. Thereby the replacement of individual modules will not be very a time consuming task.

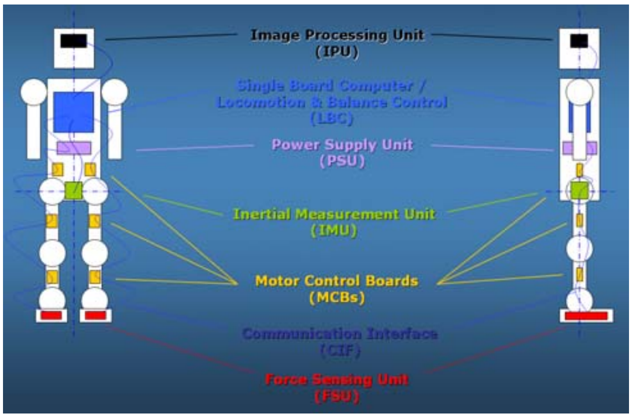

Fig. 1. System architecture

4 Sensors

4.1 Inertial Measurement Unit - IMU

The IMU measures the tilt of the robots torso in respect to the vertical line of gravity. To achieve a precise and steady result the signals of two different kinds of sensor-types are fused. Two 2-axis acceleration sensors are utilized as inclinometer to calculate the tilt for slow motion. Two gyroscopes measure the rotation velocity and are used to detect fast changes of the angles. The sensor fusion is based on a complementary filter and is processed in a signal processor (dsPIC30F4011). The IMU is mounted on the lower part of the robot's torso.

The IMU communicates via RS485-bus with the SBC and sends two 10-bit values for pitch and roll and current state information upon request to the SBC. The hardware is also prepared for CAN-bus communication and thus very flexibly applicable.

4.2 Force Sensing Unit - FSU

The FSU is used to measure the forces on the soles of the feet. Therefore four strain gages are used per foot. The strain gages are designed as full bridges and fixed on the vertices of each sole. To grant that no sinking of the foot into the ground is possible, which lead to wrong measuring data or even worse to a possible fall of the whole robot, a base was developed. Further a Plexiglas plate was mounted to protect the sensors. This is shown in Fig. 5.

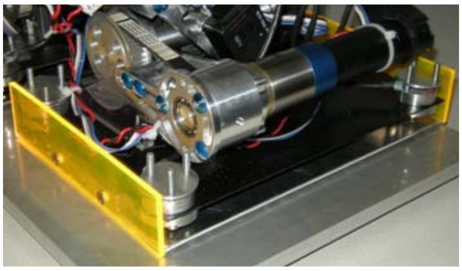

Fig. 2. Redesign of a robots foot

A signal processor (dsPIC30F4011) calculates the resulting force per leg and the Zero-Moment-Point (ZMP) of the foot. The ZMP provides important information for the advanced locomotion and balance control. ZMP-coordinates and the resulting forces are sent via RS485-bus to the SBC. Like in the other modules the hardware of the FSU is also prepared for CAN-bus communication.

4.3 Joint- and Motor- Encoder

The angle of each joint is measured using incremental encoders. Due to the tolerance of the motor gear boxes it is necessary to measure each angle at the motor and at the joint itself. By using this kind of measurement it is possible to control the deviation of gear box and joint with the appropriate motor control board. Refer to chapter 5 for detailed information about the motor control boards.

The encoders do not provide absolute joint positions, thus every encoder value has to be referenced using a certain home position during power-up. If there appears an error during walking, the robot can be immediately stopped by the remote control. After that it can return back to the home position. For this purpose we designed a separate power supply for the motor control boards and encoders.

4.4 Image Processing Unit - IPU

The IPU is based on a standard fire wire camera and on a Compact Vision System (CVS) from National Instruments (see Fig 8).

Fig. 3. Components of Image Processing Unit

The IPU is capable of identifying and locating simple objects. Object identification means that the robot can find and detect pre-defined objects and object locating means that the IPU is able to determine distances and directions of detected objects. In this stage of extension, these two features are implemented for a ball. The image processing application has been developed using NI Vision Assistant and NI LabVIEW. They are also used for controlling the moveable head. The CVS is fixed on the robots back. Information between the CVS and the SBC is exchanged using a standard RS232 interface and a simple proprietary protocol.

5 Actuators

5.1 Legs

Six Motor Control Boards (MCBs) are used as actuators to control all twelve joints of the robot. Thus, each MCB controls two motors.

Each MCB retrieves a new set point from the SBC every 10 ms and returns its current joint angles at the same time. The joints are controlled using a position control with cascaded velocity control. Additionally the deviation between motor-encoder and joint-encoder, as mentioned in 4.3, is adjusted. Infineon’s XC167 are used to read-in incremental encoder signals and to execute the required discrete-time control loops.

5.2 Head

To ease the object location, two servo motors are used to control the position of the moveable head Fig. 8). The vertical and horizontal movement of the head is solved with two Servo motors of the type HS-82MG from HiTec. The head can be turned +/-

70° horizontal and from 0° to -65° vertical by using a belt drivel. The control software runs on the embedded FPGA on the NI CVS allowing the head to be steered directly by the vision recognition application. Thus, the servos are driven by a CVS generated PWM signal.

6 Results

In this project a functioning humanoid robot, that fulfills the requirements for the RoboCup challenge, was built. Besides the mechanical structure of the legs, the robot's torso and the whole electronic system were developed and realized by the research group.

The robot is able to walk into any direction on a flat and hard underground in a stable manner. One single step is executed within approximately five seconds. Furthermore it is able to locate and kick a ball. Fig. 10 shows the robot walking towards the ball.

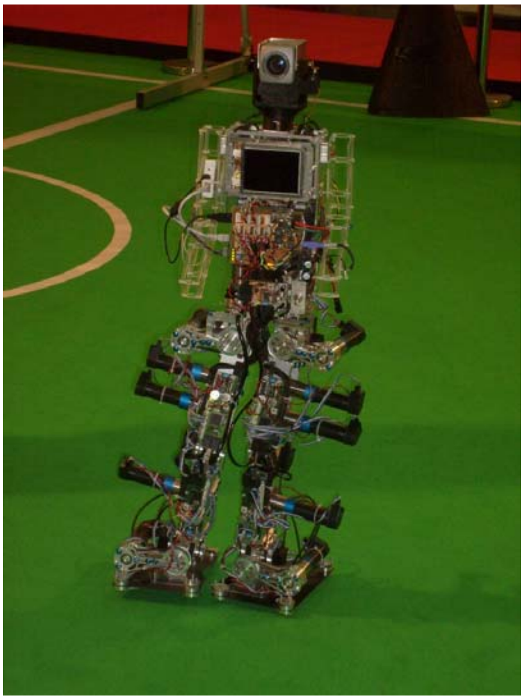

Fig. 4. Walking robot

The robot can be operated in two different ways. The first option is to use a mode switch, which is located on the robot's torso. The second option is the usage of a remote control program, which communicates with the robot's SBC via Wireless LAN

(WLAN). This program allows to wireless control the robot and read back important data of the robot.

To obtain further status information of the robot a telemetry-program may be used.

The telemetry-program is implemented as a NI LabVIEW program and can be executed on an external PC. The data transfer between SBC and telemetry-program is again performed via WLAN. Important data of the system, such as information about the different connected units, the current and desired joint angles of all joints, data of the different sensors, etc. can be monitored with this program.

7 Conclusion

In this Team Description Paper we presented the first humanoid robot of the Carinthia University of Applied Sciences. It is based on a distributed system architecture, which consists of a 133MHz Single Board Computer as central processing unit and several microcontroller-units as sensors and actuators.

We are looking forward to present the performance of our robot at the RoboCup 2009 in Graz. Due to the fact that this year’s competition is held in Austria we would be glad to raise the public awareness of robotics and science in our home country.

References

1. Albert-Jan Baerveldt, Robert Klang: A Low-cost and Low-weight Attitude Estimation System for an Autonomous Helicopter , 1997 IEEE International Conference on Intelligent Engineering Systems
2. Friedrich Wittgruber, Digitale Schnittstellen und Bussysteme, Vieweg Verlag, 2002
3. Damien Kee, Confirmation of PHD Candidature, 2003
4. Pei-Feng Chen and Tsai-Yen Li, Planning Efficient Walking Gaits in Real-Time for Human Characters, Proceeding of 2003 Computer Graphics Workshop (CG2003), Taiwan, 2003.
5. Tarizzo Alberto: A Minimalistic Approach to Walking Design for a Humanoid Robot at RoboCup, 2006
6. Tarizzo Alberto: A force Sensor Made by Diaphragm Pattern Mounted on a Deformable Circular Plate, 2006
7. P. Veronesi et al, Team Description Paper, RoboCup 2007, Atlanta, USA
8. Rene Mente, Benjamin Steinwender, Wolfgang Werth, Object Interaction of a Humanoid Robot, RoboCup Workshop Austria 2008, Villach, Austria
9. Wolfgang Werth, Rapid Development of a Moving Head for a Humanoid Robot (HWM), NIWeek, Austin Tx, USA, 2008