Team Description Paper
Humanoid Walking Machine Research Group

Philippe Veronesi[1], Wolfgang Werth[2],
Gerhard Hinterberger, Melanie Lackner, Philipp Senn, Gerald Weratschnig,
Markus Zauner, Rene Mente, Benjamin Steinwender, Edgar Siegfried Petschnig, Stefan Preimel
[1] Team Leader, [2] Scientific Coordinator

Carinthia University of Applied Sciences, Europastrasse 4, 9524 Villach, Austria
www.hwm.cc

Abstract – **In this paper an autonomous humanoid robot, which was developed by a team of seven students in the course of a 2-semester project work, is presented. The robot is based on a 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 and kick a ball.**

I. Introduction

Building and controlling a humanoid robot sets high demands on mechanical and electronic system architecture. Fascinated by this complex and challenging problem, the goal of this project was to build a functioning humanoid robot in only nine months in a project team of 7 electronics students. 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 to make participation at this competition possible. Fig. 1 shows a picture of the robot with a height of 96 centimeters and a weight of approximately 18 kilograms.

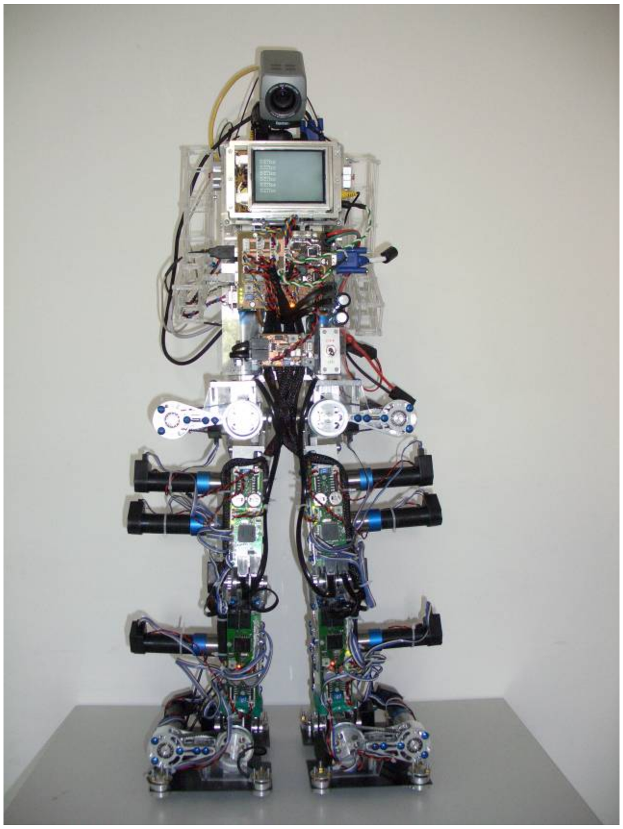

Fig. 1. Robot

II. 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), so the robot possesses 12 DOF altogether. DC motors with gear boxes and tooth belts are used to actuate the joints (see Fig. 2). The mechanical structure of the legs was bought from another university, while the upper part of the robot was constructed by the project team.

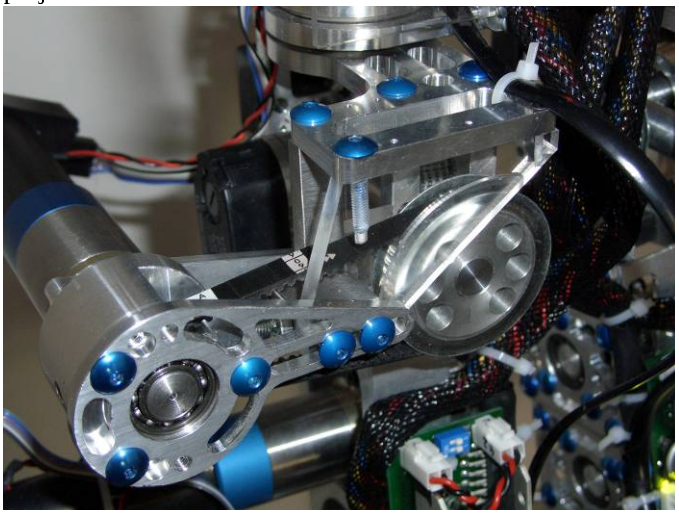

Fig. 2. Tooth belt for power transmission

III. 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 is used as central processing unit (CPU). This CPU uses InTime as real time operating system and provides a reliable base for the execution of the Locomotion and Balance Control (LBC).

The Single Board Computer communicates via high-speed serial bus interface with several sensors and actuators of the robot. Due to the distributed system architecture, it is easy to expand and individual modules can be replaced very easily.

The RS485-bus operates at a baud rate of 1.152Mbps and uses differential signaling. The Single Board Computer acts as single master and addresses slaves using an efficient, proprietary protocol.

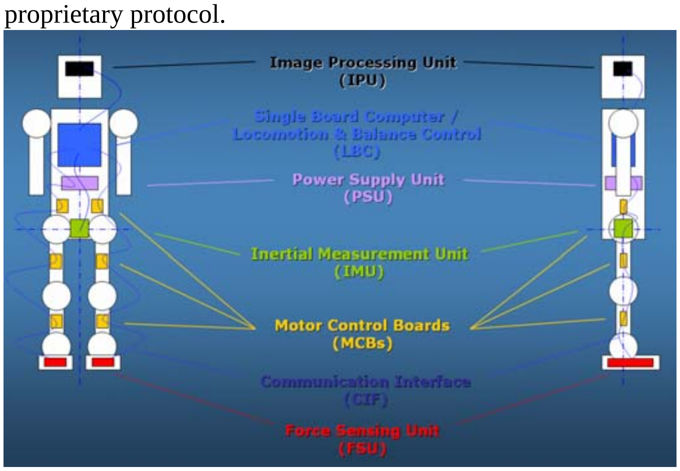

Fig. 3. System architecture

IV. Sensors

A. 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). Fig. 4 shows a picture of the IMU, which is mounted on the lower part of the robot's torso.

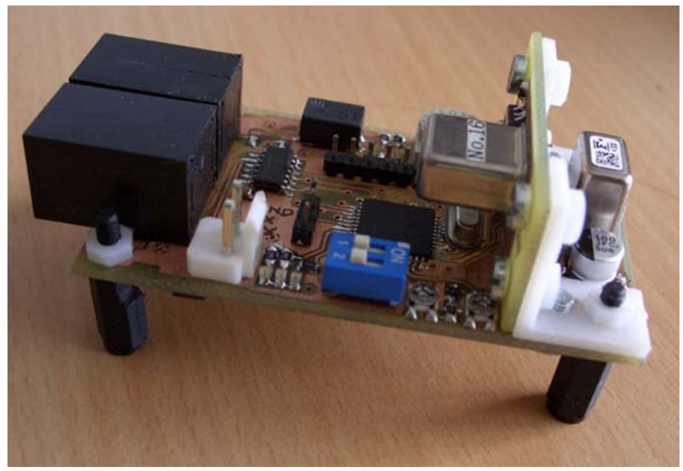

Fig. 4. Inertial Measurement Unit

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

B. 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. 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 Single Board Computer. The hardware of the FSU is also prepared for CAN-bus communication. Fig. 5 shows a picture of the FSU, which is mounted on the backside of each lower leg of the robot.

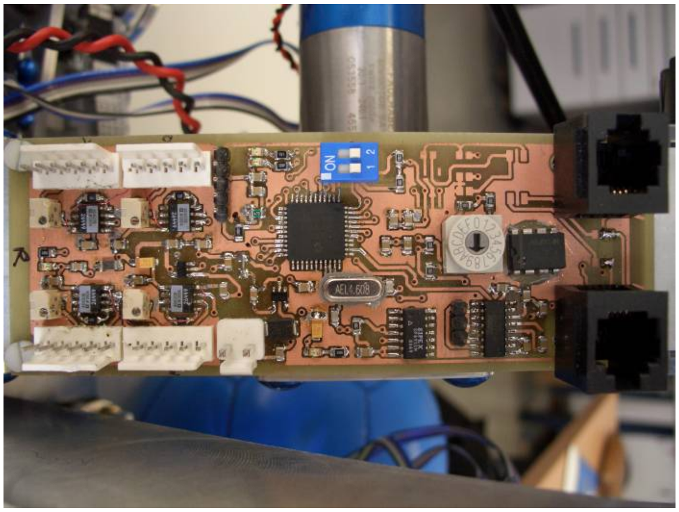

Fig. 5. Force Sensing Unit

C. *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. Fig. 6 shows one of the robot’s knees with motor- and joint-encoder. 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 V for detailed information about the motor control boards.

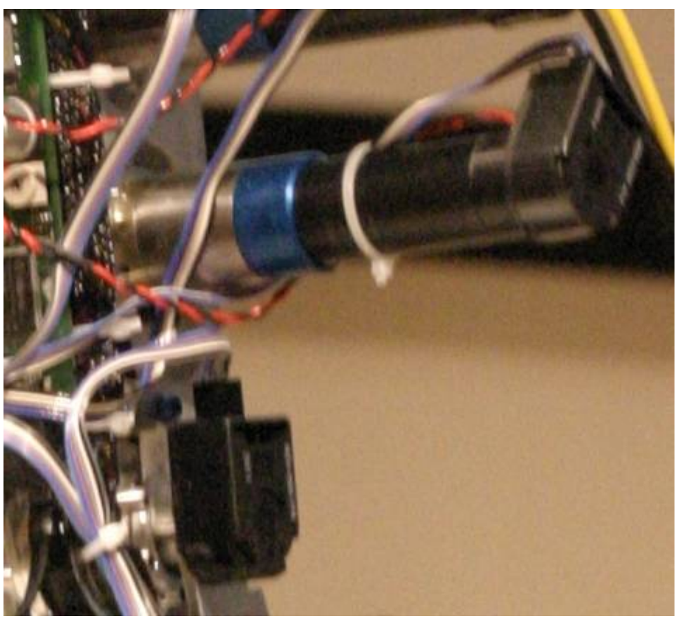

Fig. 6. Motor- and joint-encoder

The encoders do not provide absolute joint positions, thus every encoder value has to be referenced using a certain home position during power-up.

D. *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. 7).

Fig. 7. Components of Image Processing Unit

The IPU is capable of simple object identification and object location. 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 National Instruments Vision Assistant and LabView. The CVS is fixed on the robots back. Information between the CVS and the Single Board Computer is exchanged using a standard RS232 interface and a simple proprietary protocol.

V. Actuators

Six Motor Control Boards (MCBs) are used as actuators to control all twelve joints of the robot. Each MCB controls 2 motors.

Fig. 8 shows a photo of a MCB.

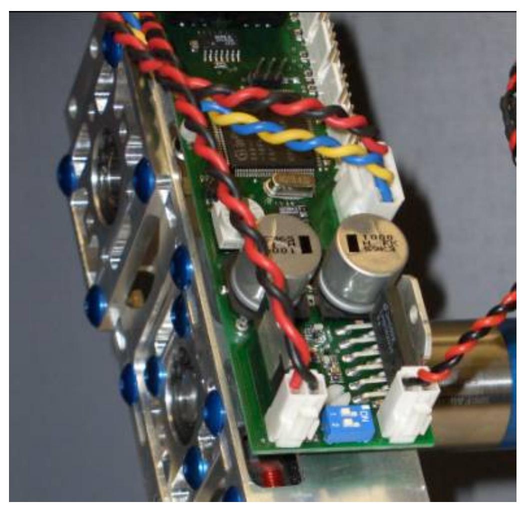

Fig. 8. Motor Control Board

Every MCB retrieves every 10ms a new set point from the Single Board Computer and returns its current joint angle 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 IV-C, is adjusted. Infineon's XC167 is used to read-in incremental encoder signals and to execute the required discrete-time control loops.

VI. Results

In this project a functioning humanoid robot, which 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 project team.

The robot is able to walk into any direction on a flat and hard underground in a stable manner. One single step is executed in approximately five seconds. Furthermore it is able to locate and kick a ball. Fig. 9 shows the robot walking towards the ball.

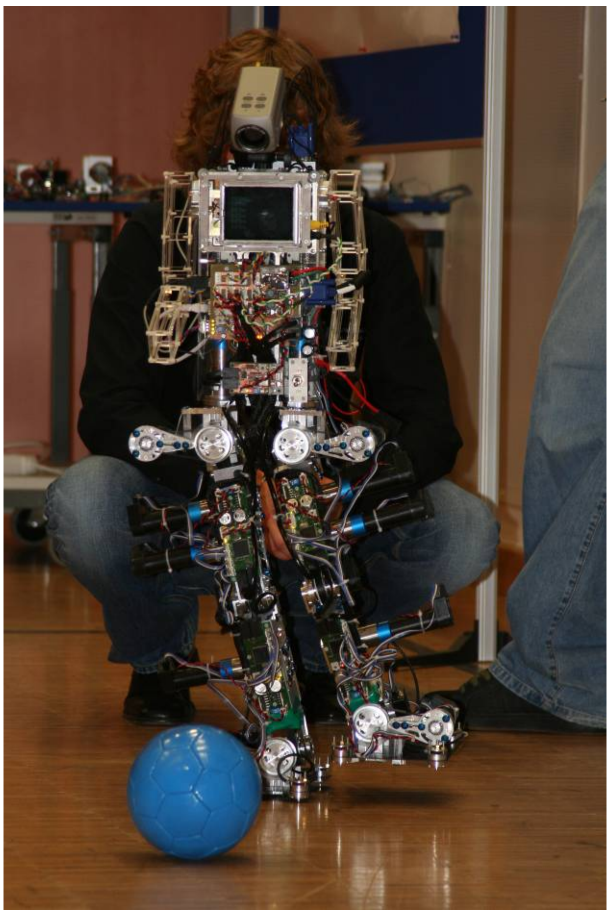

Fig. 9. Walking robot

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 Single Board Computer via Wireless LAN (WLAN). This program allows wireless control of the robot.

To obtain important status information of the robot a small display and a telemetry-program are used. The display is connected to the CPU and mounted on the robot's torso (see Fig. 10).

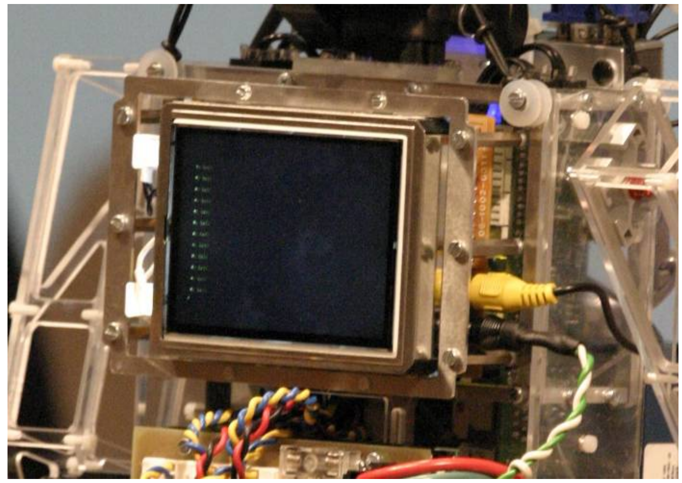

Fig. 10. Display

The telemetry-program is implemented as a LabView program and can be executed on an external PC. The data transfer between CPU 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. A screenshot one part of the telemetry-program is shown in Fig. 11.

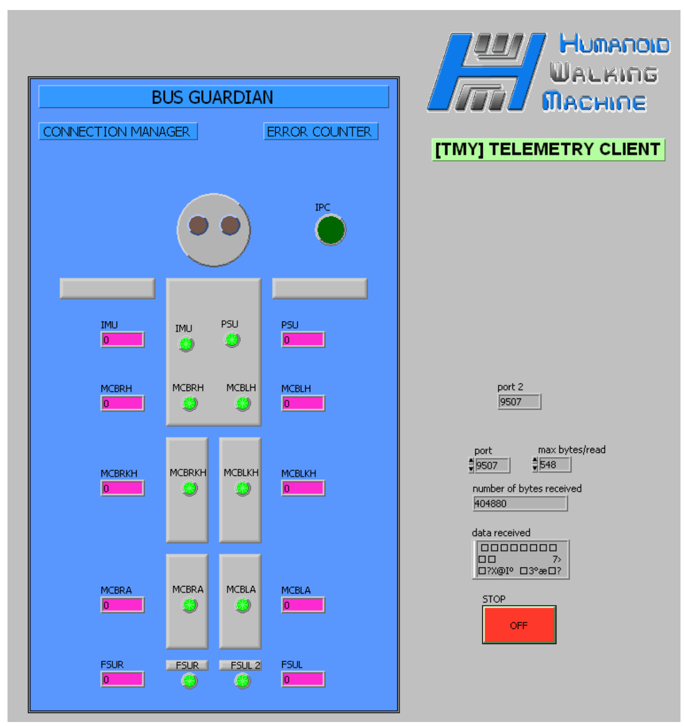

Fig. 11. Screenshot of telemetry-program

VII. 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 2007.

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] Research and Development Towards an Autonomous Biped Walking Robot Proceedings of the IEEE/ASME International Conference on Advanced Intelligent Mechatronics

[4] Confirmation of PHD Candidature, Damien Kee, 2003

[5] Planning Efficient Walking Gaits in Real-Time for Human Characters, Pei-Feng Chen and Tsai-Yen Li, Proceeding of 2003 Computer Graphics Workshop (CG2003), Taiwan, 2003.

[6] Tarizzo Alberto: A Minimalistic Approach to Walking Design for a Humanoid Robot at RoboCup, 2006

[7] Tarizzo Alberto: A force Sensor Made by Diaphragm Pattern Mounted on a Deformable Circular Plate, 2006