FUmanoid Team Description 2007

Hamid Reza Moballegh[1], Roman Guilbourd[1], Gretta Hohl[1], Michael Oertel[1], Raúl Rojas[1]

[1] Institut für Informatik, Arbeitsgruppe Künstliche Intelligenz,
Freie Universität Berlin, Takustr.9, 14195 Berlin, Germany
http://fumanoid.mi.fu-berlin.de

Abstract. This document describes hardware and software of the robots developed by the "FUmanoid" Team for the RoboCup competitions to be held in Suzhou, China 2008. The mechanical structure of the robots is an improved Bioloid construction kit, which is available for research and competition. Servo motors of the lower part of the body are replaced with Dynamixel RX28 for various reasons described in the paper. Machine vision is performed by development of an embedded camera and processor unit. Planning algorithms are organized in a new structure called Concurrent Scenario based Planning (CSBP), and are running on the original Bioloid processor board, the CM5. This paper explains the software and hardware used for the robot as well as control and stability methods developed by our team.

1. Introduction

Humanoid robots have many potential applications, which make this area very attractive for researchers. However many of the yet developed humanoids suffer from over-designed and too complicated hardware and software which is still far from the human model.

The FUmanoid team was started in 2006 in the Artificial Intelligence group at Freie Universität Berlin, which has had a successful and long history in RoboCup with the FU-Fighters team. The team has shown an excellent performance in its first year of activity by winning the 3rd place of the world RoboCup humanoid league in kid-size class, presenting the lightest and the least expensive football playing robots in their class. This is achieved by advancing several solutions in the areas of hardware and software, which will be explained briefly in this paper.

The FUmanoid project is a step towards research and development of robots which offer more real human-interaction, can perform tasks in our environment and will be able to play important roles in our daily life.

2. Hardware Design

2.1. Mechanical Structure

The actuator family used in the FUmanoid robots is the Dynamixel servo produced by Robotis inc. Korea. The motion mechanism consists of 20 degrees of freedom distributed in 6 per leg, 3 per arm and other two degrees of freedom as a pan-tilt system holding the camera.

Fig.1 shows one of the constructions used for the motion mechanism of the robots. Knee joints are considered to have an initial angle of 150 degrees which helps faster response of them during walking behavior of the robot. Efforts have been made to hold the proportions as much as possible human like. Table1 illustrates the physical measurements of the robot. To facilitate exchange of the players, all robots use mechanically the same structure.
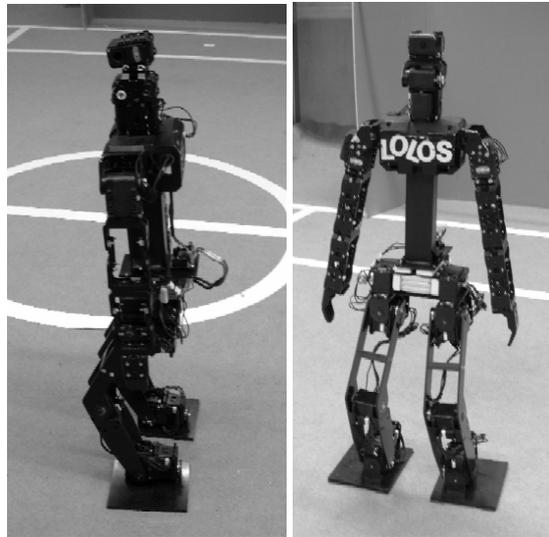

Fig. 1. Mechanical construction of the Robots

Quantity	Value	Unit
Overall Height	60	Cm
COM Height	31	Cm
Weight	2507	G
Leg Length	30	Cm
Foot Area	120	Cm^2
Arm Length	30	Cm
Head Length	8	Cm

Table 1. Physical measurements of the robot

2.2. Actuators

The actuators used in FUmanoid robots are "Dynamixel AX-12" and "Dynamixel RX-28" servomotors, produced by Robotis Inc. Each actuator has its own microcontroller which implements adjustable position control using potentiometer position feedback. It also calculates many other parameters such as rotation speed and motor load which can be accessed through a single-bus, high-speed serial communication protocol. This facilitates the construction of an extendable network of motors which can be individually accessed and controlled by a single microprocessor. The parameters of the actuators used in FUmanoid robots are summarized in table 2.

	Weight g	Gear Ratio	Max Torque kgf.cm	Speed sec/60º	Resolution degrees
Dynamixel AX-12	55	1 : 254	16.5(@10V)	0.196	0.35
Dynamixel RX-28	72	1 : 193	28.3(@12V)	0.167	0.35

Table 2. Characteristics of the servomotors used in FUmanoid Robots

2.3 Sensors

The robot has only two types of sensors: the camera and the sensory feedback from the servomotors. Although due to the single bus structure several other types of sensors could be easily integrated with the hardware, we have decided to use a minimum-number of sensors in order to avoid complexity and minimize costs, and also to develop software based control and stabilization solutions.

The vision sensor used in FUmanoid robots is an embedded module consists of an integrated CMOS camera and a microcontroller. This module is capable of detecting colored objects at the rate of 10Fps and reporting them through a serial bus to the main processor. This has helped a lot to decrease the weight of the robot. To perform computer vision humanoid robots usually need powerful computers on board, which in turn leads to higher power consumption.

The sensory feedback of the actuators includes the current joint angle, the current motor speed, and the load. Because all of this values are derived from the only feedback sensor of the actuators (the position potentiometer), the latter two values are less reliable. There are also other measured values which can be accessed through the Dynamixel serial interface, such as supplied voltage and temperature, which can be used for safety purposes. The sensory feedback of the actuators, as will be explained later in description of control and planning systems, is very useful in fall detection, and gait generation for the robots.

2.4 Processors and communications

The original processing unit of the robot (called CM5) is very light-weight and many of the functions needed to communicate with actuators and PC are available for this

platform. Therefore it is used as the main processing unit of the robot. Having the low-level vision performed on the vision module and joint position and speed control on each servo, the processing power of CM5 is enough to perform all the other tasks needed for a football playing robot, i.e. planning and stability control. The Processor of the CM5 is an ATMEL ATMEGA128 which is an 8-bit RISC microcontroller clocked at 16MHz and has a throughput of almost 16MIPS at this frequency. This microcontroller has plenty of resources, among them 2 USART modules which are used to communicate with both servo and PC sides. In the servo side 1Mbps is used as the baud rate. Each servomotor (and of course any other module such as the camera) has a unique ID for packet identification. There is also a broadcasting ID used to send the same data packet to all existing motors on the bus. On the PC side the communication is performed using a standard 57600bps RS232 protocol. This communication can be wired for robot programming/calibration) or wireless using an RS232 to WLAN converter which is used in a running game to send the required signals such as start and stop to the robot. CM5 programming has been done in C language.

3. Software Design

Fig.3 shows the block diagram of the software which runs in the robot's main processor. The program consists of 4 main blocks:
- **Operating System:** Contains all low level routines to access the hardware of the robot and also the actuators. It also provides multi threading capabilities needed for the planning system and vision.
- **Vision:** Contains higher level image processing algorithms such as recognition of landmarks and other objects based on the color region information delivered by the camera module. Self localization is done using particle filtering. The particle set is updated in vision based on the sensor model as the robot sees new objects. It can also be updated based on the motion model as the robot moves.
- **Planning:** The planning system of the robot is based on a multi layer, and multi thread structure. The layers are named Strategy, Role, Behavior and Motion. Each layer contains a Scenario which runs in parallel with the scenarios in the other layers. A scenario in a higher level can terminate and change the scenario running in the lower level; however it is usually done in synchronization with the lower level scenario to avoid conflicts and instabilities. (such as stopping the walking motion while one of the feet still flies).
- **Network:** Mainly responsible for the wireless communication of the robot with the other robots or the referee box.

In addition the camera module has its own software which is written mostly in assembly language to be efficient enough to process the online image from the camera despite the limited resources of its processor.
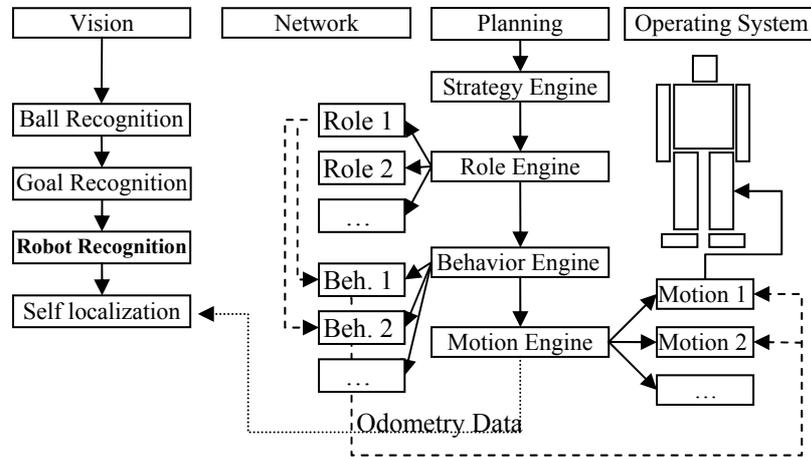
Fig. 2. Structure of the control software

4. Stabilization and Control

Stabilizing humanoid robots is a challenging subject which has attracted many researchers who have developed widely varying techniques. These techniques range from simple and static COG methods to poorly dynamic nonlinear control methods using multi-DOF underactuated inverted pendulum models. A novel approach was developed for the biped walking stability problem by McGeer, who pioneered the idea of passive dynamic walking [1]. This approach which is both simple and direct has been followed by Collins, Wisse and Ruina and has been improved with different techniques to obtain 3D walking stability [2].

Both 2D and 3D passive dynamic walkers receive their energy from changes in height of their COM as they walk down a shallow heel. Therefore the original passive walking is not suited to applications such as football playing in which the robot should not only walk on a level surface but also change its velocity and direction very often. To solve this problem, further researches have presented several methods of pumping energy into a passive walker such as torso control [3], active toes [4] and virtual gravity [5].

The aim of our biped walking research is to develop a walking technique which uses as few sensory data as possible (i.e. only the joint angle data) and provides stability over a wide range of velocities. To examine the present solutions and be also able to study new ideas, a simplified model of the robot has been simulated with ODE and its walking stability has been tested in simulations. Using this simulator, some new techniques have been introduced to improve walking stability and to control the walker.

However implementing the simulated control ideas in a real robot is as difficult as re-doing the whole work despite of the simulated results. This is because of the vast difference between the simulated and the real platform. Actuators used in most of the humanoid platforms are servomotors, which have normally a high grade of damping regarding the gear reduction ratio and have also strong limits in their maximum speed and/or applied torque. This is very disadvantageous as the energy of centre of mass is of great importance in passive dynamic walking. A direct torque control is also provided by almost none of the commercially available servomotors.

As a test, the friction of the ankle actuators of each foot was reduced by removing a gear from each, so that they could only function as low friction joints with position sensors, the data derived from this sensors are then used in the control program which finds the stance foot at each step and controls all active actuators regarding to the stance angle. The robot has been able to walk several steps on a slope.

To have the passive walking controlled and supplied from own energy of the robot, one should be able either to switch the actuators to act as passive free running and active in different walking phases or to decrease the stiffness of the servos and use them in a mixed way both as sensors and actuators. Using the later technique, stable walking at velocities up to 40Cm/s has been achieved.

Because several other necessary behaviors of the robot are fully active and mostly semi-static, a key-frame interpolator is developed and used to generate stable trajectories for different behaviors. This unit together with the walk controller forms the so called "Motion Engine".

References

1. McGeer, T. 1990. Passive dynamic walking. In: International Journal of Robotics Research 9(2):62–82.
2. A Three-Dimensional Passive-Dynamic Walking Robot with Two Legs and Knees, Collins, S. H., Wisse, M., Ruina, A. In: International Journal of Robotics Research, Vol. 20, No. 2, Pages 607-615, 2001
3. Haruna, M., Ogino, M., Hosoda, K. and Minour, A., Yet another humanoid walking - Passive dynamic walking with torso under a simple control In: Int. Conference on intelligent robots and system, 2001
4. Sven Behnke, Jürgen Müller, Michael Schreiber: Toni: A Soccer Playing Humanoid Robot. In: RoboCup 2005: 59-704.
5. Asano F. and Yamakita M. Virtual Gravity and Coupling Control for Robotic Gait Synthesis. In: IEEE Trans. on Systems, Man and Cybernetics, Part A: Systems and Humans, Vol. 31, No. 6, pp. 737-745, November 2001.
6. Erik V. Cuevas, Daniel Zaldívar, and Raúl Rojas: Incremental fuzzy control for a biped robot balance. In: International Conference on Robotics and Applications 2005, October 31 - November 2, 2005 Cambridge, USA
7. Eric V. Cuevas, Daniel Zaldívar, and Raúl Rojas: Dynamic Control Algorithm for a Biped Robot. In: 7th International Conference on Control and Applications, Cancún, Mexico, May 18-20, 2005.
8. RoboCup Humanoid Team of the Freie Universität Berlin, http://fumanoid.mi.fu-berlin.de/