Team MU-L8 Humanoid League – TeenSize Team Description Paper 2014

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Abstract. This paper gives an overview of the hardware and software of the Team MU-L8 teen-sized humanoid robot. The Marquette University's (MU) Team MU-L8 is a new entry into the TeenSize league in 2014 and has designed and built its own teen-sized humanoid robot, MU-L8, inspired by the University of Bonn's NimbRo-OP humanoid robot. This paper details the hardware, mechanical and software design of MU-L8. Also described are the program code and approach for our software platform supporting team strategy, kick and ball search motions, vision, and localization algorithms. This is Team MU-L8's first entry for RoboCup, although the team advisor has participated in prior RoboCup Standard Platform League (SPL) Open competitions at his previous institution.

1 Introduction

Team MU-L8 is applying to the RoboCup Humanoid – TeenSize league for the first time. Team MU-L8's advisor, while employed at another university, has led student teams to compete in RoboCup events since 2005 including the Standard Platform League RoboCup Japan (2009) and Mediterranean Opens (2010, 2011), tying for third place in the RoboCup 2011 Mediterranean Open using the Nao humanoid robots. Team MU-L8 is committed to competing in the RoboCup 2014 Humanoid – TeenSize competition in Brazil if selected and will provide a referee knowledgeable of the rules during the competition.

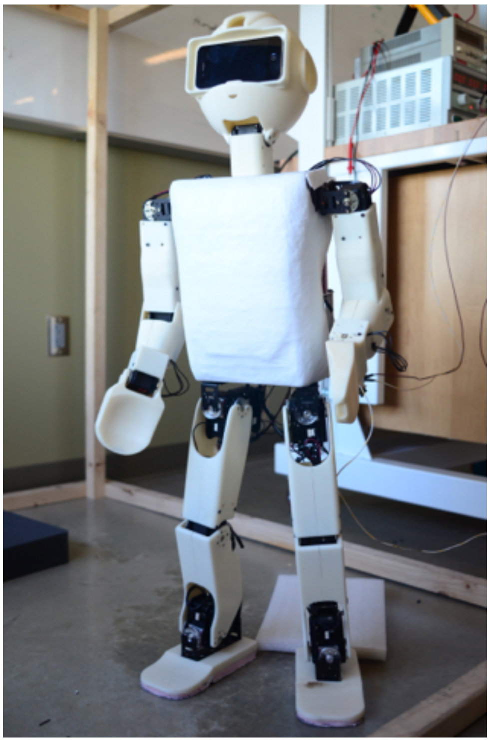

Figure 1 The MU-L8 Humanoid Robot

2 Hardware and Mechanical Design

Team MU-L8 [1] has developed its own teen-sized humanoid robot, MU-L8, (pronounced "emulate"), inspired by the University of Bonn's NimbRo-OP robot [2]. The limbs and head were created using a 3D printer, and the remaining electronics were designed using off-the-shelf components.

2.1 Specifications

MU-L8 measures 91.5cm tall and weighs 7.6kg. It has 24 total DOF provided by Dynamixel servos. Each leg has six MX-106T actuators; each arm has three MX-64T and two MX-28T actuators. The neck has two MX-64T actuators. All limbs are 3D printed ABS plastic and the torso is machined aluminum.

2.2 Mechanical Design

We designed MU-L8 to be 3D printed from ABS plastic so that others may easily replicate the robot and use it as platform for their own research. To encourage replication, we considered the affordability and availability of building materials, including off-the-shelf electronic components. Social interactivity was another important consideration because we will use the robot for HRI (human-robot interaction) research in addition to RoboCup competition. To address this need, the head of MU-L8 was designed to accommodate a smartphone (e.g. an Android OS-based phone), which allows it to interact socially with a user through speech recognition, speech generation, and facial expressions. This Smartphone Intuitive Likeness and Expression (SMILE) device will also have a mode for touch-based user command entry to configure and control the robot [3]. We note that the screen of this smartphone can be turned off in order to avoid distracting another team's vision.

It was important that the central torso be made of durable aluminum to protect the computer stack. We modeled the torso on the NimbRo-OP torso, with modifications to simplify the design, as shown in Figure 2, so that a student would easily be able to build it in a standard machine shop. The torso was machined from common 3mm thick aluminum sheets for component shelves, and the uprights were made from 9.5mm square rods. Figure 1 shows MU-L8 with an encased torso that was made from molded thermoplastic for protection and aesthetics.

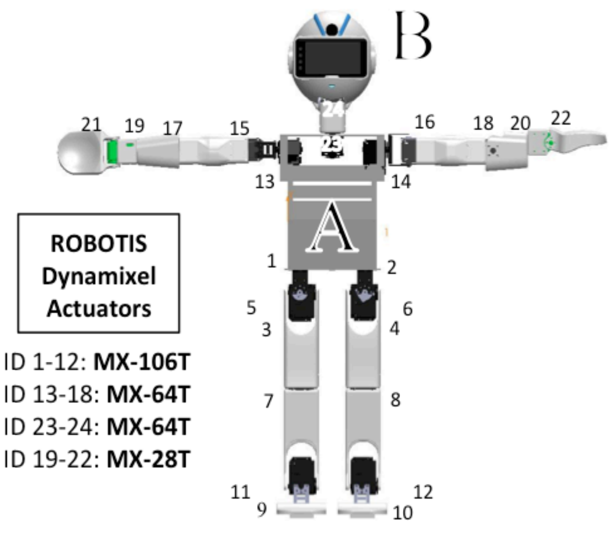

Fig. 2. A) The torso holds the on-board computing components and power supply. Computing components consist of an Intel NUC 53427HYE and a LG Nexus 4. Power is supplied by a 14.8V 3600mAh Li-Po battery, which rests above motors 1 and 2. B) The Logitech C905 720p webcam is housed in the head along with an android phone used for social interaction.

To fasten one motor to another, we purchased aluminum brackets from ROBOTIS [10]. There is an HN05 in each shoulder that connects motor 13 to 15 and 14 to 16, as shown in Figure 3. The HN08 is a larger frame that holds 2 perpendicularly oriented MX-106 motors. This setup is found in each hip and ankle to allow smooth abduction and extension of the legs and feet.

There are several challenges associated with 3D printing. Strength and support are the most important aspects, since playing soccer places punishing force on the robot's frame. For this reason, we designed each part to withstand significant torque and impact. The process of designing, prototyping, and testing each limb was crucial in meeting the torque and impact criteria mentioned above. The prototyping process began with simply designing the limb around the Dynamixel motors. Once the initial prototype was printed using a Dimension ES1200 rapid prototyper, we could see how the limb performed on the robot. Tests usually exposed design flaws that affected either the strength of the limb, the ease of assembly/disassembly, or the range of movement. The limb was then redesigned to correct any flaws before printing it again.

2.2 Sensors

The MU-L8 humanoid robot's embedded system controls the communication between actuators, sensors, and other devices, allowing the hardware to communicate with higher-level software. The hardware used in MU-L8 consists of an Intel NUC 3rd generation i5 (1.8-2.8 GHz) mini-PC, Dynamixel Robot Actuators, 720p Logitech C905 webcam, and the Nexus Android Smartphone with 3-axis gyroscope and 3-axis accelerometer.

3 Software Design

Team MU-L8 is developing its own software, including software to perform vision, motion, and behavior functions, in an Ubuntu Linux environment using C++ and Java. This software will be used for developing motions for kicks, locomotion, and role behaviors for the attacker and goalie. Future MU-L8 software is anticipated to incorporate ROS.

3.1 Software Architecture

The framework for MU-L8 primarily consists of three subroutines running concurrently. These subroutines include a vision module, a motion module, and a behavior module. The vision module is responsible for the identification and localization of the ball and other key objects. It relays its findings of MU-L8's surroundings to the motion module, which decides how best to act in response to the visual cues. The behavior module not only checks sensory inputs for falls and voltage drops, allowing proper corrections to be made as needed, but also implements the team and individual soccer behavior functions by coordinating vision and motion.

The software system uses the C++ programming language to call low-level hardware functions. The low-level hardware interfaces can access the camera and the gyroscope and accelerometer sensors located in the smartphone, and can modify joint angles and stiffness. The three main subsystems are the vision subsystem, the motion subsystem, and the behavior subsystem. The behavior subsystem interfaces with the camera and the servomotors respectively. The behavior module interacts with both the vision and motion subsystems to implement the sense, plan, and act cycle.

3.2 Vision

The vision subsystem uses the Logitech webcam to capture video images, process them, and localize objects of interest (e.g. a soccer ball). We start with OpenCV image processing functions to extract data from a video frame captured by a web camera. The image is passed through a threshold filter, and all except the desired colors are removed from the image. The desired color is highlighted in white, and the rest is colored over with black. In order to eliminate background noise, linear convolution is utilized within a Gaussian filter. After the image is passed through the threshold filter, shown in Figure 3, objects are detected on the basis of color and size. The largest white object remaining after the video frame is passed through the threshold filter is selected as the desired object.

Ball Localization

After the image processing has taken place, all that remains is a black and white image where black is the color to be ignored, and white highlights the unique features of the desired color. In order to localize the ball's position, the robot first finds the largest white object contained within the image. Once the largest object has been detected, a grid structure, shown in Figure 3, is placed on the image. The grid square containing the largest mass of the largest object is then selected to be the area where the ball exists (highlighted by the green dot in Figure 3). After the program decides upon the current position of the ball, the motors are moved until the ball is in the grid's center square.

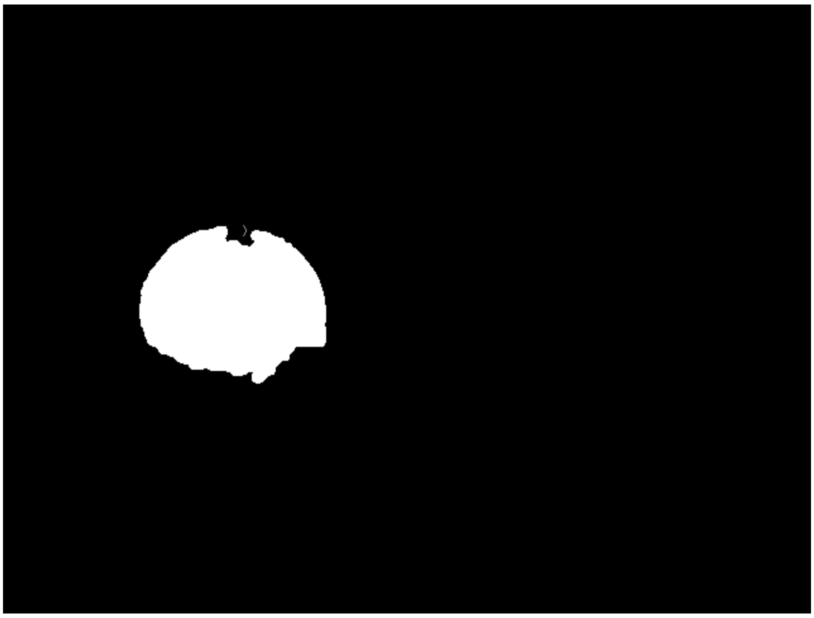

Figure 3 Video frame passed through threshold filter

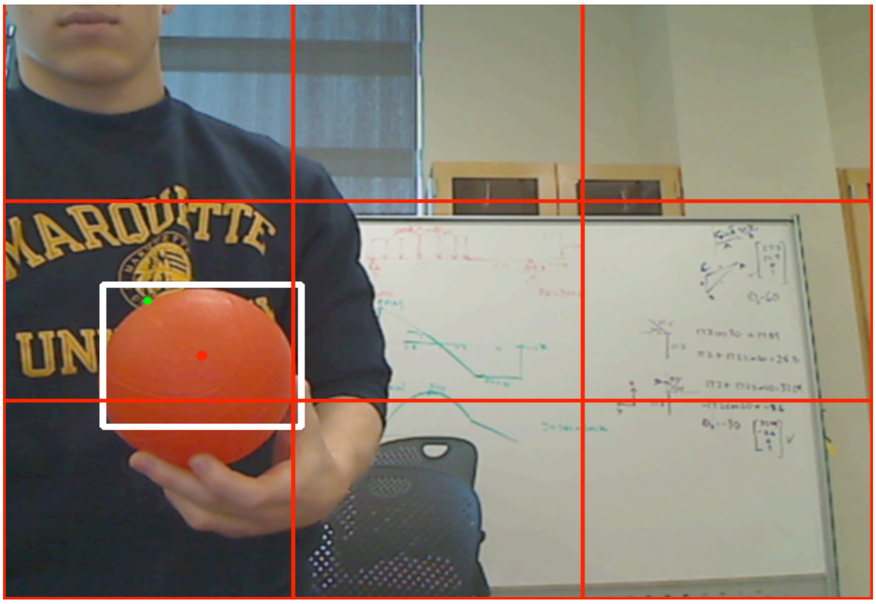

Figure 4 Localization grid placed over the video frame.

In order to localize the robot with respect to its position on the field, in our first RoboCup competition we will use the ball and goals to perform a rudimentary estimation of its position. We anticipate using more complex localization and tracking algorithm techniques, such as Kalman filters, in the future.

3.3 Motion

The Motion subsystem is used to implement the control of the actuators for coordinated kicking, searching, and walking motions. The individual motions that MU-L8 is able to perform are stored as text files, then processed and loaded into memory at startup. This design allows for quick and easy changes to be made to the motions, and it also allows for several backups to be made. The motions are demonstrated in the qualifying video.

3.5 Behavior

Our team behavior strategy will separate the roles of the robots into goalie and attacker/defender. One robot will implement both the defender and attacker mode. In the defender mode, the behavior subsystem will guide the attacker/defender to work with the goalie to defend the goal. While in attacker mode, the robot will make an aggressive, forward charging attack on the opponent's goal. We anticipate making use of the inter-robot communication mechanisms in the software platform with further development, but this is currently not implemented in MU-L8.

5 Research Interests

Team MU-L8 has demonstrated its interest and preparation for RoboCup soccer in its participation and presentation in the Humanoid Robot Soccer Workshop, held at the IEEE Humanoids 2013 conference in Atlanta, GA [1]. MU-L8 is being developed not only to play soccer but also to conduct research in humanoid robot health coaching [4]. We are also conducting research in learning creativity in robots, as well as applications for emotional robots and human-robot interaction [3][5].

6 Qualification Video

Team MU-L8's demonstration of the working code with the minimal required behaviors can be seen in the YouTube video http://www.youtube.com/watch?v=HFxbTlk4SDs. Further refinement and improvements are planned if MU-L8 is accepted for qualification to compete.

Commitment
Team MU-L8 commits to traveling to Brazil to participate in RoboCup 2014 if selected and will provide a referee knowledgeable of the Humanoid League rules.

7 Summary

Team MU-L8 has demonstrated the minimal capabilities for qualification and request qualification to the RoboCup 2014 Humanoid TeenSize competition. If selected, the team will continue to make improvements to its soccer playing capabilities and program code. As of the date of this TDP, February 20, 2014, we have made satisfactory progress and anticipate major improvements in our vision, motion, locomotion, and behavior code prior to the RoboCup 2014 competition.

8 Acknowledgements

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9 References

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