AUT-UofM Humanoid TeenSize Team Description Paper

RoboCup 2014 Humanoid TeenSize Robot League

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Abstract. This document introduces AUT-UofM Humanoid joint team for participating in Humanoid TeenSize Robot League in RoboCup 2014 in Joao Pessoa, Brazil. This team was founded in 2013 on collaboration between AUTMan humanoid team from Amirkabir University of Technology, Iran and team Snobots from University of Manitoba, Canada. Our humanoid TeenSize research is mainly based on both universities' experiences provided from long time participation in RoboCup humanoid league in recent years. A brief history of Team AUT-UofM and its research interests will be described. Future work based on the humanoid Teen-size robots will also be discussed. Our main research interests within the scope of the humanoid robots are in a range from humanoid robust walking to accurate localization and to able robot deciding more wisely based on a knowledge base.

Keywords. RoboCup 2014, humanoid joint team, localization, robust walking, knowledge base.

1 Introduction

RoboCup is pursuing the goal which states "By the year 2050, develop a team of fully autonomous humanoid robots to win against the human world cup champion team". Though, this means, forcing teams to have larger robots. On the other hand, for teams to be able to afford the financial issues in making larger robots to take part in RoboCup competitions all over the world, it is necessary to collaborate in other teams' research programs and make joint teams. This is one of the RoboCup goals to encourage different groups from different universities and countries to have collaboration with each other. Amirkabir Robotic Institute and Mechanical Engineering Department of Amirkabir University of Technology have been remarkably participating in Humanoid League of RoboCup competitions from 2011 [1]. Therefore, team AUTMan and Snobots decided to join forces and formed a joint team AUT-UofM in 2014.

2 Recent Achievements

Team AUTMan KidSize participated with great success during last years' RoboCup events all over the world, especially in RoboCup2013, Eindhoven, the Netherlands, where this team placed 2nd among Humanoid KidSize teams. Team Snobots from the University of Manitoba is a very experienced team and has competed in the RoboCup humanoid league since its start in 2002 [2]. The team performed well at RoboCup 2013 in Eindhoven and won a 3rd place in the Technical Challenge awards.

Both teams have also published their research extensively. In the last five years the team members have published six papers in the RoboCup symposium and are planning to submit several papers to the 2014 RoboCup Symposium.

3 Development for 2014

In 2014, team AUT-UofM focuses on the following new developments: (a) develop methods for successful collaboration between teams from separated by geography, culture, and politics, (b) create a novel Teen-sized humanoid robot design, (c) generating a new analytical walking engine with better balancing and push recovery, (d) improved methods for vision-based localization. There have been several previous attempts at collaboration in the RoboCup humanoid league. However, the collaboration was usually limited to teams that were based in close proximity, or teams that had clearly separated areas of concern (e.g., teams develop hard or software only), or to teams that developed robots individually and then formed a team of independent players. The team AUT-UofM faces several challenges. Not only is the team located halfway around the world in Canada and Iran (e.g., scheduling meetings is difficult because of the different time zones), but members also come from very different cultural backgrounds. In addition, there is political tension between the political leaders of Iran and Canada. Furthermore, both teams have previously made great contributions and developed successful designs in hardware and software. Therefore, we expect a close collaboration between team members that will result in a new hardware design which utilizes strengths of both teams' previous designs and also a close collaboration in the development of the necessary software modules (e.g., ball detection, landmark detection, localization). In spite of all these problems that need to be overcome, we believe that such collaboration is important for the future of RoboCup as the cost of participation increases dramatically when teams need many expensive players. Lessons learned from this and similar close collaboration will be crucially important for the future of the RoboCup humanoid league.

In technical aspects, we will use ROS as our framework packages in order to make our robots more reliable and flexible. We also step toward a more analytical walking than our previous walking algorithm in KidSize class which could reach a high speed but low stability in previous competitions. Using ROS make us able to use a complicated decision stage based a knowledge base which it is also used for localizing robots more accurately. This team description paper provides a brief overview of our relevant research since our participation in RoboCup competitions and of current joint works which are imminent to be used during the competitions.

4 Hardware Design

4.1 Mechanical and Electrical Design

Currently, both teams have developed their own Teen-Sized humanoid robots as shown in Figure 1: AUTeen and Scrappy.

(a) (b)

Figure 1: (a) “AUTeen” TeenSize Platform Design (b) “Scrappy” TeenSize Platform

4.1.1 AUTeen

AUTTeen is 105cm tall and weighs 7.5Kg. New robot’s kinematic structure is with 20 degree of freedoms (DOF). The design is such that urged us to use 6 DOFs for each leg, 3 degree of freedoms for each arm. Robots camera will be hold by 2 servo motors as a Pan-Tilt mechanism. Serial mechanisms have been used in legs to make the robot as simple as possible. The Dynamixel MX and RX series manufactured by Robotis will drive the robot joints [3]. We have used MX106 series in leg joints and RX64 series in arms and RX24 series in neck. For more performance and energy efficiency, we have used two motors in our knees.

In this robot, we have focused on robustness, weight reduction and also fast reaction. For more compatibility and sensory information fusion, we adopt CM9.04 (OpenCM9.04 is an open-source controller that runs under 32bit ARM Cortex-M3 from ROBOTIS.co [4]) as a low level controller and Device Communication Manager (DCM) in our robots. We also use USBzDXL as a direct motor controller for Dynamixels [4] actuators from main processor, this component is needed to communicate with devices like actuators and sensors in different method such as I2C, RS485, Serial TTL, analog and etc. CM9.04 is just used for sensor fusion (low level filtering) and user interface function. The CM9.04 controller working on 72MHz and communicates with upper layer (PC) on serial interface @1Mbps. In low-level computation on this board, we drive three types of different sensors: Motion 9DOF IMU sensor, integrated foot pressure sensors based on FSR sensors, internal actuators load, speed and absolute position sensors for debugging mode. The CM9.04 runs lower-layer algorithms which can provide 3D posture of COM in pitch, roll and yaw at more than 100Hz with high resolution of orientation by filtered and combination of internal gyro, accelerometer and manometer sensors of GY-80 IMU [5]. Figure 2 shows low-level controller and main controller and peripheral connected device.

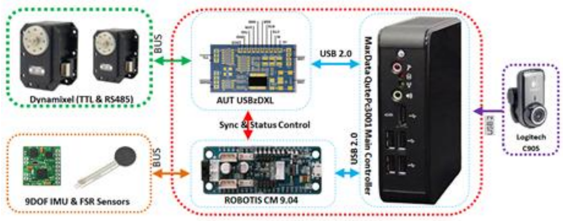


Figure 2. CM9.04 low-level controller & main controller and peripheral connected device

In AUTeen, MAXData QutePC-3001 [6] mini embedded board is used as a main controller. High performance and low power consumption are the main factor for using this kind of main boards as a main processor in humanoid robots.

4.1.2 Scrappy

Scrappy is a new experimental design for a Teen-Sized humanoid robot that focuses on a design for a running robot. The walking speed of humanoid robots has increased greatly in recent years as most teams now implement stable and robust ZMP or CPG based dynamically stable gaits. However, even the best humanoid robots are only able to jog slowly. This is due to: (a) the power to weight ratio of the electrical motors is not high enough to allow for the fast motions necessary for running, and (b) the high

impact forces during running make it necessary to have compliant control in the joints. To greatly improve the power to weight ratio of the robot, a minimal number of actuators are used. Scrappy only uses seven active and four passive DOFs in its design. A single leg of the robot consists of one active DOF and two passive ones. The active DOF is implemented via a Dynamixel RX64 servo and rotates the hip in the lateral domain. The two passive DOFs implement a spring and damper system in the frontal and lateral plane of the leg's ankle respectively. These two passive DOFs give the robot a compliant ankle joint that is able to absorb the high forces during landing while jumping, jogging, or running. The upper body of Scrappy includes three active DOFs: one moves the torso in the frontal plane, and two move the left and right arm in the lateral plane respectively. The DOFs are implemented via Dynamixel RX-64 servo motors. The head of the robot includes two active DOFs to pan and tilt the camera. These DOFs use GWTech RC servos that are controlled via a standard PWM.
Processing of the robot is provided by a DMP RB-110 processor board. The RB-110 is based on a Vortex x86DP based system on a chip (SOC) board. The processor is a 32 bit x86 compatible processor that runs at 1 GHz and the system includes 256MB of RAM. The RB-110 can run DOS, Windows, and Linux based operating systems. We developed a small lightweight Debian based distribution as the base of our system. The RB-110 board is particularly suitable for building of complex robots such as humanoid robots, because it includes several peripherals for input and output that are usually not found in general purpose processors. For example, it includes 24 general purpose IO (GPIOs) and 16 PWM channels for input and output as well as 8 analog to digital converters. It includes the necessary hardware to control the Robotis AX and Dynamixel RX servos directly via a half-duplex UART or differential RS-485 bus and supports 3 * USB 2.0 and a I2C bus. The RB-110 includes an Ethernet connector and also includes a Mini PCI slot which can host a VGA controller card or a WIFI card. Scrappy includes the following sensors: a UVC compatible webcam for vision and a three axis gyroscopes and three axis accelerometers mounted in the torso. The webcam is connected to the robot via the USB 2.0 interface and the gyroscopes and accelerometers use the I2C bus.

5 Software Development

5.1 Motion

Team AUT-UofM is going to use inverted pendulum method as his base of walking method. Inverted pendulum method is our base of walking method. B-human team could adopt an inverted pendulum walking which diminishes double support phase and can reject some minor disturbance due to keeping inverted pendulum walk like [6]. Some optimizations have been done to the method as listed below:

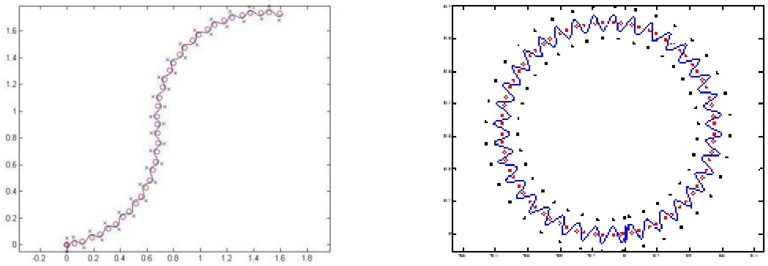
1- There were some gaps between transmissions from straight walking to Omni directional walking in the paper. Since it was not certainly defined how the sufficient parameters (s, r, x, $\dot{x}$) can be found in an Omni directional walking, so a cost function has been used and by optimizing in each parameter selection step, perfect parameter for the next walking step has been found. This cost function can be defined as below:

$$J = \frac{1}{2}w_1x^2 + \frac{1}{2}w_2(x - x_d)^2 + \frac{1}{2}w_3(s - s_d)^2 \tag{1}$$

“r” always assume 0, which is the optimized parameter [6].

2- Together the disturbance rejection which was explained in the paper, we add a heuristic push recovery (the same as we were doing in the past) to increase the disturbance rejection capability.

In Figure 3 the results of the cost function optimization for finding the best inverted pendulum parameter for a turning maneuver is shown. It is obvious that the optimization method could find a good-looking walking behavior. In this part in addition to walking engine we also work on whole body controller which designs other motion activity for our robot.



(a) (b)

Figure 3: The generated trajectory using new cost function for finding the next inverted pendulum parameters. The red dots shows origin of each step, the cross signs are the origin of inverted pendulum and the blue lines is the trajectory of COM in a turning maneuver.

5.2 Cognition

In cognition (as previous or not), tasks are done in three successive layers. Each layer will feed the next one. It contains some modules which work parallel:

Segmentation Layer: In the first layer we process wide-angle YUV images from a Logitech C905. A set of random pixels are selected in YUV color space and a Look up table is constructed based on. This Look up table is a mapping from YUV color space to a set of colors and assigns a class label to every pixel. Meanwhile, using 3D tree similar pixels are categorized in labels and known color space grows faster.

$$YUV\ Color\ Space\ \rightarrow\ Set\ of\ Table$$

$$Where\ YUV\ Color\ Space = \{0, 1, \dots, 2n\ - 1\} and\ set\ of\ Lables = \{s_0, s_1, \dots\ , s_m\}.$$

Then we segment the input image by these sets. It is worth mentioning that the Lookup table will improve performance dynamically.

Feature Extraction Layer: In this layer, at first, moments of every region are calculated. Then these moments are used to measure region’s features like eccentricity. Afterwards we determine the green horizon by generating vertical lines at first. By doing so we conquer the processor limitations because we look for the post goal above the green horizon and look for the ball, the robots and other clues under the green horizon. In the ball detection process, Newton-Taubin algorithm is used to calculate Curvature of the objects [8]. We find the green horizon by applying a simple optimal output-sensitive algorithm named Chan's algorithm which takes $O(nlogh)$ time [9]. Another module processes segmented image to locate the field objects. It does a color transition level operation. To generate color transitions, each pixel along each scan line is considered, and wherever the color class label of a pixel differs from that of the previous adjacent pixel, a transition is generated. Then we use the image coordinates of each transition to determine the start color class label and end color class label.

Object Recognition Layer: There, we down sample the segmented image. Then we detect the potential field objects like ball, goal-posts, field lines, corners, T-junctions, x-crossings, obstacles, utilizing color, and size and shape information [7]. Afterward by inverting the projective mapping from field to image plane distance and angle to each detected object is estimated [10]. As localization is one of the important modules every robot needs, we chose to use the wire stack. It generates and maintains consistent world model by feeding the detections from perceptions. Also, it does the data association by considering multiple hypotheses and tracking of multiple objects attributes [11].

5.3 Robot Navigation

Every robot in dynamic environments needs path planning and navigation based on the planned path. Humanoid robots navigation has some more difficulties than other mobile robots due to their bipedal walking.

J. Garimort and A. Hornung have solved the challenges by implementing footstep planning and navigation algorithms for humanoid robots [12-13]. We have used footstep planner package for navigating and finding the optimal path with the map providing the obstacles positions. The map is provided by the localization module. The planner is based on SBPL and capable of dynamic re-planning. The supported planners algorithms are: ARA^*, AD^*, R^*. As the foot parameters differ for each robot, we changed the parameters to meet our new built robots' configuration. So, they plans path based on new parameters.

6 Conclusion and Acknowledgment

This report described the future technical plans and works done by the AUT-UofM Humanoid TeenSize Robot Joint Team for its entry in the RoboCup 2014 Humanoid TeenSize League which has been supported by Amirkabir Robotic Institute and Mechanical Engineering Department at Amirkabir University of Technology (Tehran Polytechnic) with collaboration of University of Manitoba, Canada. AUT-UofM team's focus for the first year of RoboCup competition has been on developing a new TeenSize Platform, localization, motion behavior, and vision module due to our past and relevant experience in various RoboCup leagues, especially AUT-UofM Humanoid TeenSize Team which will be appropriate in Humanoid Robotics. We look forward to continuing and expanding our above researches with the new humanoid robots. For further information and to be familiar with our previous and new publications and recent activity done in the humanoid community and for seeing more pictures and videos, please see our official websites.

Commitments

Should our application to compete in RoboCup be successful, we commit to the following:

1. We will present a team at the RoboCup WorldCup in Brazil.
2. We will make at least one team member with sufficient knowledge of the rules available to act as a referee

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