AUTMan Humanoid Kid Size Team Description Paper

RoboCup 2016 Humanoid Robot League, Leipzig, Germany

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Abstract. This document introduces AUTMan humanoid joint team for participating in Humanoid Kid Size Robot League in RoboCup 2016, Leipzig, Germany. This joint team was founded in 2015 on collaboration between two teams from Amirkabir University of Technology (Tehran Polytechnic), Iran and University of Manitoba, Canada. A brief history of Team AUTMan and its' research interests and directions for future research will be described. Our main research interests within the scope of humanoid robots are to propose a new open platform 3D-printed kid size robot, based on the new changes due to long-term road map for the future of the league, active balancing, running robots, accurate localization, and strategic reasoning for soccer.

Keywords. RoboCup 2016, humanoid joint team, open platform, 3D printed, active balancing, running robots, localization, strategic reasoning.

1 Introduction

RoboCup, as one of the robotics sporting events in the world, have focused on soccer as a challenge problem for artificial intelligence and robotics [1]. Humanoid league, as the youngest league of RoboCup, which started his work from 2002, have some significant changes during these years. Especially, by introduction of some open platform robots, like DARwIn-OP [2], Nimbro-OP [3] and THOR-OP [4], teams can easily purchase those platforms and use them for entry to different levels of RoboCup, in state of designing and building their own. Recent development in the humanoid league, by introducing the long term road-map, which incrementally improve the league towards reaching the goal of 2050, brings some new challenges to the league. Especially in size definition of kidsize league, it brings some limitation in use of the aforementioned platforms. From the time of humanoid league long term road-map introduction, teams try their best to adopt themselves to the new changes. But the humanoid robotics community feels the lack of new and convenient open platforms which really will ease the researches in this topics. RoboCup is pursuing the ultimate goal of community, which states "By the year 2050, develop a team of eleven fully autonomous humanoid robots to win against the human world cup champion team" [5]. To do so, they encouraged universities toward making some joint research groups, which can collaborate with each other in some particular protocols. In this case, they can share their knowledge, experiences and organizational abilities in order to manage the new group well. Cooperation of Amirkabir University of Technology (Tehran Polytechnic), Tehran, Iran and University of Manitoba, Winnipeg, Canada, is one of the most successful evidence [6]. To spread the defined collaboration in 2014, we now are focusing on developing a product which can be easily used by other research groups. The introduction of our new 3D-printed Open Platform kidsize robot to the humanoid league community, is the main focus of research for our joint group. We hope, we can come to a first prototype by the end of this year and can start to commercialize it for next step. This is a new step, defined between two groups in the way of producing an open commercialized platform, despite having several initiatives directed at suitable cooperation protocols. Due to this facts, we continue the cooperation for our team for RoboCup humanoid kidsize league 2016 based on this fact, and extend our future activities toward this goal.

2 Development for 2016

In 2016, the goal of the collaboration between these two teams and also participation in RoboCup 2016 is three-fold.

1. First, the main focus of whole team is to develop a fully open platform 3D-printed kid size robot which will be based on the new humanoid long term road map.
2. To focus more on the basics of localization, behavior, team play and collaborations between robots.
3. To extend our collaboration in this sub league and continue to demonstrate the feasibility of joint teams in RoboCup.

3 Hardware Design

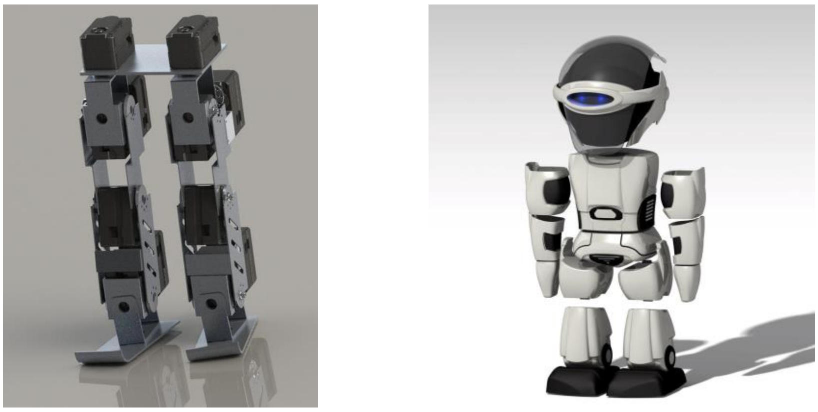
KIARASH-OP (Kid Inspired Autonomous Robot Augmented with Sense of Human Open Platform) is 60cm in height and 3.5Kg in weight. The new robot's kinematic structure has 20 degrees of freedom (DOF). The design uses 6 DOFs for each leg based on Herkulex DRS-0401 smart servo series and 3 degrees of freedom for each arm based on Herlulex DRS-0201 smart servo series. The camera of the robot is mounted on a 2 servo pan and tilt mechanism with the use of Herkulex DRS-0101 servo series [7]. For this year, we are using new servos from DST Robot Company in state of using the Robotis company servos. By comparing both companies' products, in the following table, we can see that the servos are not much difference. We choose Herkulex smart servos since of its low price.

Table 1: The comparison of two servo actuators from Robotis and DST Robot Companies

	Herkulex DRS-0402	Dynamixel MX-64T
Dimension/weight	56mm(W)×35mm(D)×38mm(H)/123gr	40.2mm(W)×61.1mm(D)×41mm(H)/126gr
Reduction ratio	1:202	1:200
gear material	Super reinforced metal	
Max stall torque	5.1N.m@14.8V(52kgf.cm@14.8V)	7.3N.m@14.8v
Max speed	0.162s/60°@14.8v	78rpm@14.8v
resolution	Approximately 0.02778° (12969 steps/360°), (max 32768 steps)	0.088

KIARASH was made of two parts: aluminum structure for placement of actuators and electrical devices, and carbon fiber body cover for anthropomorphic designed and shock absorption. To reach efficient and human-like walking, our robot's feet design, takes some inspiration from the actual human foot. For smooth lift-off leg, the cycle shape is designed at the end of the foot. Also we consider 12 degrees inclination between two legs, for better stability during walking.

We have two level electronic hardware in KIARASH, in top level we use MAXData QutePC-3001 [8] mini embedded board as a main pc and a self-designed modular header board as a controller. Communication protocol and the block diagram of the electronic subsystem is shown in Figure 2. Processor used in main board of robots is STM32F103 which calculates commands control. ARM cortex-M3 is a processor which designed for real time processing system. Reliable performance of processing of this microcontroller, computing power, top RAM, fast response to interrupts, low power consumption are reasons for choosing this processor. Also in the main board of robots, for simple debugging and online accessing to all of information we used one LCD on robot body. In effect of low battery voltage, actuator parameters will vary in a wide range. To solve this problem, it is used self-design regulator. This is regulators with respect of thermal protection, current limitation and short circuit protection which will have definitely long life.



(a) (b)

Figure 1: KIARASH-OP structural design (a) aluminum structure (b) carbon fiber body cover

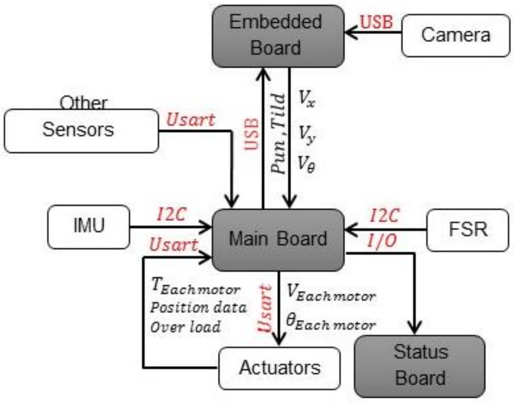


Figure 2: Robot electronic system block diagram

For calculating orientation and position of the robot related to the global reference, we use proper sensors and filters. We used multiple filter such as Kalman filter and complementary filter to have less error in estimation.

3.1 Real time operating system (RT-OS)

In KIARASH-OP, we use RL-RTX operating system that is designed for microcontroller with ARM core. This system provides possibility of creating programs with various tasks in the same time. It's necessary to mention that multiple factors was be effective for choosing this kind of real time operating system such as being free in MDK-ARM of KEIL software (Figure 3).

4 Software Development

4.1 Software Architecture

To develop an architecture for our software system, we will use the ROS [11] packages to improve the past developed experiences obtained in the AUTMan Humanoid Robotics Group.

4.2 Simulation

Our intention for this year is to make a program, which in that, we try to simulate our robots (as well as the opponent's robots) in special circumstances given before. It should be noted that our given circumstances are similar to the competition ones. In ROS [12], we have RVIZ that simulates the motor postures, but we need a special simulator in order to simulate our own game plans and also the communication between two robots and changing place between goalkeeper and players in an almost real circumstance. The main reason for this is to prevent motors from depreciation and to test the codes easily. We also intend to make the program user-friendly, so that it wouldn't be hard for others to use.

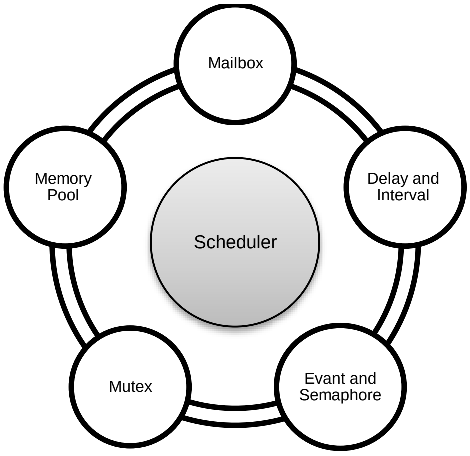


Figure 3: RL-RTX operating system

4.3 Biped walking

For achieving the robot walking process, we need to divide it into two parts (a) walking pattern planning and (b) dynamic posture stabilization. Up to now, we just have worked on walking pattern planning and hope to develop dynamic posture stabilization for walking on inclined surfaces in near future. In walking pattern planning, we consider the inverse pendulum model of the robot based on equation (1) and find the(x_{ZMP}, y_{ZMP}), assuming forward displacement of the mass center is a sinusoid function (Figure 4). By using inverse kinematic, we can find the trajectory of robot [9].

$$\begin{cases} y_{ZMP} = y_{mc} - \ddot{y}_{mc}\dfrac{l}{g} \\ x_{ZMP} = x_{mc} - \ddot{x}_{mc}\dfrac{l}{g} \end{cases} \tag{1}$$

where (x_{mc}, y_{mc}) is the forward displacement of mass center position, which is on the robot foot.

4.4 Vibration Reduction Controller

While the robot walks, the swinging leg vibrates and it can cause some problems with landing. We should find the angle that minimizes the foot vibrations. Figure 5, reveal the use of spring in the robot new design. Here, we note the transfer function which provides the relation between the present angle and desired one. Equation 2 represent the transfer function between the present angle and desired one.

$$H(s) = \frac{\theta(s)}{\psi(s)} = \frac{\frac{k}{ml^2}}{s^2 + \frac{k}{ml^2}} \tag{2}$$

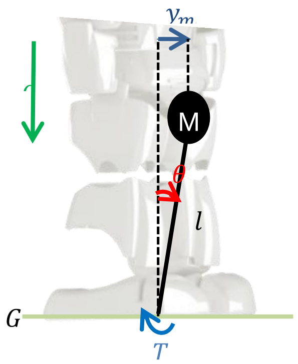


Figure 4: Inverse pendulum model

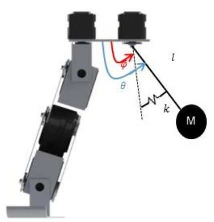


Figure 5: Springs used to reduce the foot vibrations

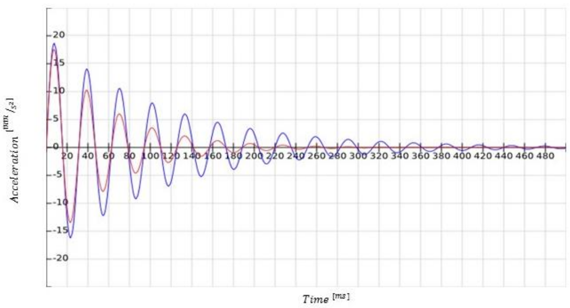


Figure 6: Graph of acceleration over time while the robot is standing on one foot, red line by controlling vibrations and blue line without controlling vibrations

4.5 Kick Foot Motion

After determination of kicking trajectory, we should determine the ZMP in a new condition. To stabilize the robot, the ZMP should be on the foot area. There are many methods to execute it, such as linear quadratic regulation and cart-table controller. We are working on this method, by using source codes of B-HUMAN SPL team [10], and improving the aforementioned source code.

4.6 Cognition

We use Logitech C920 as eyes of our robot to give it the ability to see and recognize the objects in the playing field, same as human. Cognition contains two main problems: (a) image processing and (b) localization. In an image processing, we have two parts: (a) object perception and (b) object recognition. In object perception, we find objects in the field, by their shapes and in object recognition, we recognize what each shape that we found in the first part actually is.

Color classification: We process wide-angle YUV422 images from a Logitech C920. A set of random pixels are selected by human supervision in the image and a Lookup table is constructed based on it. This Lookup table is a mapping from YUV color space to a set of colors and assigns a class label to every pixel. For generating this table the k-d tree algorithm categorize similar pixels in labels that makes the known space grow fast. For example, we use this algorithm to recognize green color and find play field borders.

Regioning: in this part, at first, we find some objects by their shape type with the help of vertical scan and segmentation algorithm (Object perception).

Vertical Scan and Segmentation: The main purpose of segmentation layer is to find an approximate coordination of objects in the image by clipping color labeled ROIs. The ROIs, at first, are rectangles made by a vertical scan line algorithm, to improve the performance of this algorithm a convex hull of field and outside this hull will be ignored. Afterwards the adjacent segments are merged and make shapes. The identity of shape is guessed by heuristics which either a circle (the ball) or a line (the field lines and the goal posts) this strategy significantly improves the performance since the color labeling is not efficient anymore.

For object recognition, first, we should convert our image to edge base segments, so that we can use Hough transform algorithm [11] (Hough line and Hough circle) to recognize ball and lines. Beside detected lines by Hough line algorithm, we find land marks which help us to find corners and center circle.

Localization: We use the Unscented Kalman Filter to approximately define the robot position in the field and have a proper world model. This world model enables the robots to share the other teammate's objects positions and decide based on a consensus of opinions. With world model and localization, we can use different game plans in the match.

4.7 Robot Navigation

We have used combination of footstep planner package and obstacle avoidance controller for navigating and finding the optimal path with the map providing the obstacles positions [12]. The map is provided by the localization module. The planner is based on SBPL and capable of dynamic re-planning. 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.

(a) (b)

Figure 7: (a) detection of occluded ball, (b) detection line intersections

5 Conclusion and Acknowledgment

This report described the technical plans and works done by the AUTMan Humanoid Kid Size Robot Joint Team for its entry in the RoboCup 2016. AUTMan team's focus, for the new start at RoboCup competition, has been on a new Kid Size Platform, localization, motion behavior, and vision module due to our past and relevant experience in various RoboCup leagues. For further information, please refer to our publications. The reader can also find more pictures and videos of our robot on our official websites.

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