MRL Team Description Paper for Humanoid KidSize League of RoboCup 2014

Mostafa E. Salehi[1], Reza Safdari, Erfan Abedi, Bahareh Foroughi, Amir Salimi, Emad Farokhi, Meisam Teimouri, and Roham Shakiba

Mechatronics Research Lab, Dept. of Computer and Electrical Engineering,
Qazvin Islamic Azad University, Qazvin, Iran
Email: [1]m.e.salehi@qiau.ac.ir
Web: http://mrl.ir

Abstract. This team description paper presents the specifications of the MRL kidsize humanoid robot system which contains different parts including robot vision, motion control, world modeling, self-localization, and behavior. MRL humanoid team is developed under the RoboCup 2014 rules to participate in the kidsize humanoid soccer league competition in João Pessoa, Brazil and like the last year we will introduce a referee with sufficient knowledge of the rules available during competition. We use DARwIn-OP as our base platform and we have modified this platform in vision, motion control, world modeling, self-localization, behavior, embedded control board, and also the robot embedded operating system as will be discussed in the related sections.
Keywords: RoboCup 2014, Kidsize Humanoid League, Bipedal Locomotion, Artificial Intelligence, Embedded System Design

1 Introduction

RoboCup uses the soccer robots leagues aiming to develop a team of humanoid robots that can win the human world champion soccer team in 2050. In the Humanoid league, fully autonomous human-like robots play soccer against each other. The robots are capable to handle a stable walk, perform a visual perception, have a proper model for the ball, players, and the field, and self-localization. The MRL project was started in 2003 in the Mechatronics Research Laboratory in Islamic Azad University, Qazvin branch looking onward to enhance the knowledge of robotics and the MRL humanoid kidsize soccer league is aimed to develop a humanoid platform for research and education. Our research center has the honor to hold the RoboCup IranOpen from 2003 to 2014. Our humanoid soccer playing team has participated in RoboCup and IranOpen Humanoid League from 2011. In 2012 and 2013 we had the honor to be in the top 8 teams among 22 participating teams. This year we are planning to participate in the kidsize humanoid competition for the 4th time in RoboCup 2014 in João Pessoa, Brazil. Our mission is to fulfill our study in motion control, vision, world modeling and localization, artificial intelligence, and robot embedded system design.

MRL Humanoid Kid Size team consists of one Ph.D., 8 graduate, and 8 undergraduate students from software, hardware, electronics, and mechatronics. The other team members are: Mohammad R. Najafipour, Mostafa Mahmoudi, Maryam Naderian, Ashkan Farhadi, Alireza Tabaie, Naeem Ale Ahmadi, Hamed Sharifi, Pourya Shahverdi, Mostafa Azarkaman, Mohammad Aghaaabasloo, Elahe Mansoury, Mojtaba Ghanbari, and Mohammad R. Khodabakhshi.

2 Overview of the System

We have used DARwIn-OP (Dynamic Anthropomorphic Robot with Intelligence Open Platform) [1] in our soccer playing team for RoboCup2014. The kinematic structure with 20 DoF can be seen in Fig.1. Physical specification of the robot is illustrated in Table 1. Our developments for the kidsize humanoid robot include the design and construction of modular software architecture based on the Upenn RoboCup released code [2]. The software contains robot applications including autonomous motion and walking controller, self-localization base on vision, planning, and communication. Each robot is able to detect the ball and goal by scanning the field, walk towards the ball, and kick it. We have implemented MUSH (MRL User Shell) to simplify and expedite the configuration, compilation and running multiple robots simultaneously.

Fig.1. kinematic structure of DARwIn robot.

Table 1. Physical measurements of the DARwIn.

Feature	DARwIn
Height:	45.5 cm
Weight:	2.8 Kg
Walking Speed:	24 cm/s
Degrees of freedom:	20 in total
Servo motors:	20 MX-28
Sensors:	Touch sensor and IMU
Embedded PC board:	Our customized embedded core board

DARwIn-OP consists of a USB camera, two embedded processing systems, gyro and acceleration sensors, servo motors, batteries and some user interfaces such as switch and LED. Images are captured by the USB camera, the camera sends image signal to the main CPU board. The CPU processes the image data to detect positions of ball, goals, and other robots by color-based image processing. A particle filter is employed to localize the robot in the soccer field. We have also used wireless communication between the robots. Exploiting the vision and network data we select the next behavior of the robot according to the robot role and the priority of the behaviors. The defined behaviors are composed of simple motions to support more complex tasks.

2.1 Electronics and hardware

After about two year of using DARWIN-Op platform in MRL Humanoid lab we felt the need to design our own electrical platform to make our robots more stable, powerful and efficient. Participating in Robocup 2013 and also 2012 was a great chance to find system shortcomings. Then we have decided to design and manufacture a customized processing unit in order to increase both the processing power and robot stability in hardware. In our yearly roadmap in hardware design we predicted that till Robocup 2014 we'll have an electrical platform including four main parts including Core module, Sub-Controller Module, Image Processing Module and the PMU (Power Management Unit) in which all of them are included in two PCBs (Printed Circuit Board), one as power management system and the other as main processing unit.

Previously in Darwin-op we were using FIT-PC2 as our core board with an embedded single core Intel Atom Processor with clock frequency of 1.6GHz. The problem with this core was the performance of the system that made us unable to make great improvements in our algorithms. In order to satisfy increased performance requirements, FIT-PC2 is being replaced by our new core board. This core board includes a quad-core ARM Cortex-A9 CPU with 1.7GHz clock speed in each core and also a 2GB LPDDR2 RAM that enables us to handle more processes at time.

Second phase in designing our electrical platform was to design the sub-controller. The sub controller used in Darwin-op was CM730, working based on STM32 an ARM Cortex-M3 Microcontroller. There was no problem with the whole sub-controller system but there was huge problem with its connectivity, forcing us to pick up the robots for service in the matches. Cm730 had the problem of disconnecting from pc time to time. We solved this problem with replacing cm730 with another onboard controller module. According to our roadmap we expect to have these modules to our robots by robocup2014.

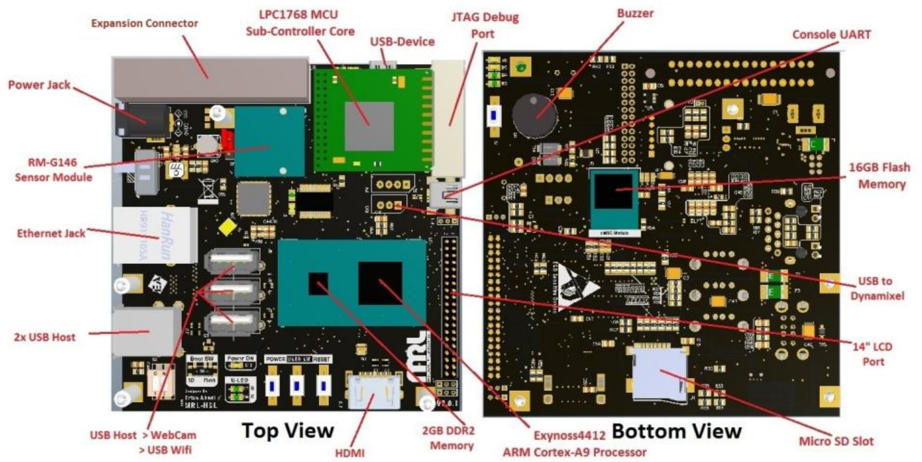


Fig. 2- Our new designed embedded processing board.

2.2 Motion Control

In last decades, interest in biped robots, especially humanoid robots, has been growing up. Stable walking is one of the critical challenging problems in these kinds of robots and many researches have been done to achieve a walking model similar to human. Central Pattern Generator (CPG) is one of the biological gait generation models which can produce complex nonlinear oscillation as a pattern for walking. In this section we introduce our methodology that is used to modify the DARwIn robot motion. In our model we use polynomial equations for the support leg and Truncated Fourier Series (TFS) equation for the swing leg in sagittal plane and produce one step. For balancing, the same values are generated for both the swing leg and support leg with Truncated Fourier Series (TFS) equation in frontal plane. Evolutionary algorithms are used to optimize equation parameters and achieve the best speed and performance in walking. We have produced single step cycles in 0.48s and record the angular position value of each joint in each 0.04s (angular position for both swing leg and support leg). Fig.3 represents some samples for angular positions for hip, knee, and ankle joints which are fitted to sinusoid and polynomial mathematical equations.

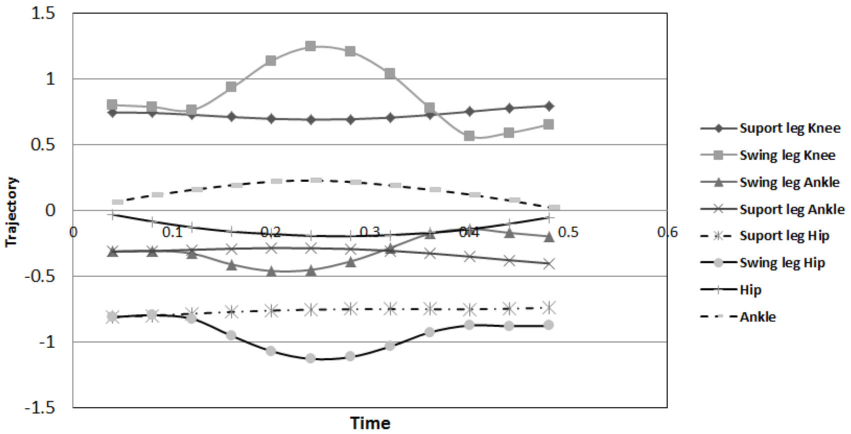


Fig. 3- Samples of angular positions for Hip, Knee and Ankle joint.

2.3 Robot Vision

Vision is one of the most important interfaces for robot perception [3]. The main vision sensor is a camera that is located in the robot's head. This camera model of DARwIn-OP is Logitech C905 that uses USB2 connection with two Megapixel 640×480 resolutions (up to 1600×1200, 10fps or 1280×720, 30fps) in YUYV color space capturing 30 frames per second. For robot's color learning phase we used color look-up table for segmentation. One of the leading problems of this approach is its dependency to the light intensity and the other problem is that it takes a pretty long time to set the color look-up table manually. The light intensity is an uncontrolled factor in humanoid robot operational environment. According to our previous research [4], the HSI color space is less affected to variations in light intensity comparing to other color spaces. To solve the first problem we used HSI color space and for the second one, we deployed autonomous color look-up table which the TT-UT Austin villa team has already implemented [5].

Our vision module consists of two subsystems: "Mobile Object Detection" and "Stationary Object Detection". Stationary object detection detects goal posts, field lines and landmarks. In contrast mobile object detection detects ball, opponents and teammates. We have employed expensive algorithms in term of processing load, so we run these algorithms conditionally, to decrease the robot processing load, yet it can impel reduction of robot self-localization precision [6].

2.4 World Modeling

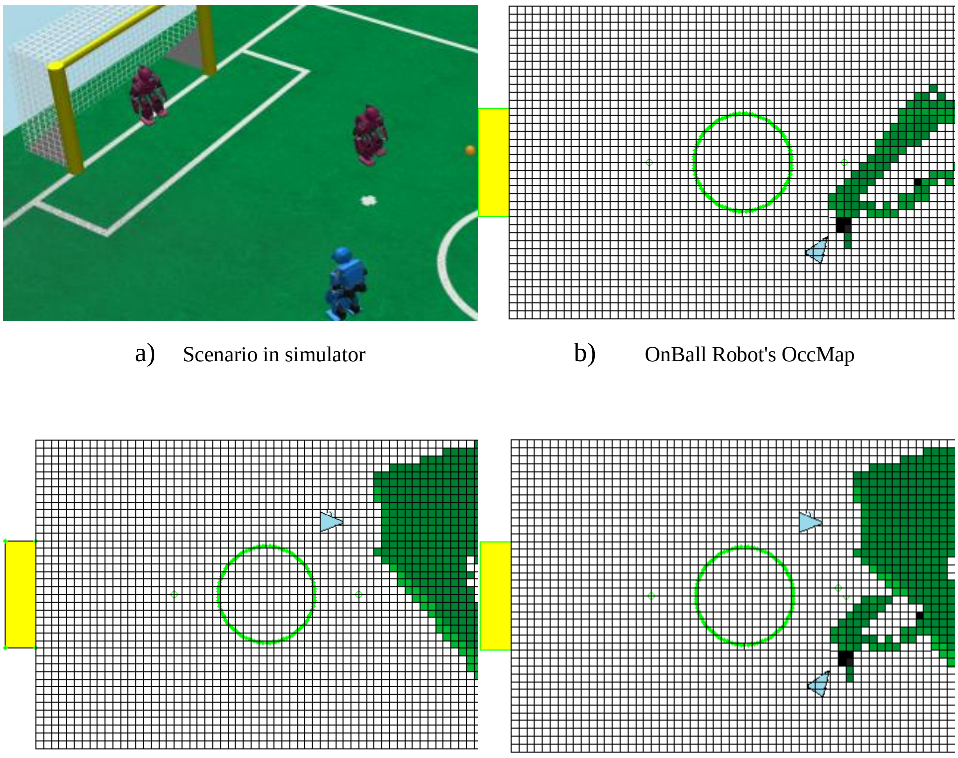
World model is a key component in intelligent and autonomous robots. Modeling the system consist of a model for each static and dynamic object in the field of play. These models are formed by the incoming data from the sensors of the robot. Due to the noise and uncertainty of observations and limitations in humanoid sensors, tracking the surrounding environment of the robot is an important challenge. This year we have modified the robot self-localization and developed ball and obstacle models.

- **Ball model**

Ball is the most important moving object in the field that should be tracked by every player in the field depending on its role. Since the ball data is noisy, we use a Kalman filter to decrease its noise. After applying the filter, we create a model of ball to be used in behavior control layer. Our goal is to have a stable and reliable model. Vision data, odometry, kicking and passing, affect this model and also affect the uncertainty of the ball with specified ratios. Each robot, can share its own model with the other team mates, this cooperation plays an important role in the same-color goal detection in humanoid soccer league. We would also improve the ball model of each robot by other robot's ball model.

- **Co-Operative Occupancy Grid Map**

Considering the high probability of collisions in operational environment, robots need to model the environment for intelligent activities like planning and obstacle avoidance. We have used a co-operative Occupancy Grid Map in which the robot's environment is divided into specific number of cells [7]. In our experiments, the robot's field is divided into 5400 cells and each cell size is 10×10 cm^2. The current state of each cell and the probability of being occupied is determined with a floating point number between [0,1], in which 0 indicate free cells as well as 1 indicating occupied cells. We employed a count model for calculating this probability which is based on the number of times the cell has been occupied. The output of vision module which is the field of view (FOV) data of the robot is mapped to corresponding cell in Occupancy Grid Map using Bresenham line algorithm [8]. Then we update the count model counters according to the state of the cell, using the co-operative occupancy grid map which uses the other teammates' data. We cover parts of the field which are not in robot's FOV. Each robot broadcasts free and occupied counters of last seen cells as well as receiving them from its teammates; the new robot's perception is preferable to the other robots data about that cell. This way robot has better knowledge of occupancy cells of the field which leads to a better game planning. In Fig 5, a sample scenario of generating co-operative occupancy grid map in collaboration with two robots of the blue team is shown.



a) Scenario in simulator b) OnBall Robot's OccMap

c) Forward Robot's OccMap d) Co-Operative OccMap

Fig. 5- Co-operative occupancy grid map.

2.5 Self-localization

An essential capability of a soccer playing robot is to robustly and accurately estimate its position in the field. With respect to the limited FOV and limitation in robot sensors, tracking the pose is a complex problem. SDMCL [9] model has a good accuracy and low cost, but suffer from low stability. In [10], a hybrid approach based on fuzzy grid and EKF is presented that has good stability and high accuracy as well. Unscented Kalman Filter (UKF) that represents state space with a Gaussian distribution has the ability to track position with high precision. Moreover, this filter is lightweight in time complexity. However, it suffers from global positioning and kidnap problem. One the other hand particle filter (PF) can be used in all localization problems. But PF's stability and time complexity are not as good as UKF. This year we utilized a hybrid localization method based on the PF and a population of UKFs. Whenever samples of PF are focused, a UKF is initialized in the pose of PF. therefore, there is no need to update PF. Each UKF sample has a weight that is smoothly changed with respect to the vision perception. If the weight of best UKF is less than a predefined threshold, PF samples are initialized with the sensor model. Low weight

UKF samples are removed and closed ones are merged. With the proposed localization method, high precision as well as low time complexity is satisfied.

2.6 Behavior Control

According to our point of view about behavior control with a hierarchical nature and based on UPennalizer framework, we have considered working on primitive problems in behavior layer. As our contributions in the behavior, firstly we have applied most of the improvements in the bottom layer as player’s action parameter optimization. This year we concentrated on three problems. The first one is path planning [11] which we have discussed about previous year. This year we implemented our proposed algorithm [12] on robot. Also we are working on another method for obstacle avoidance using a fuzzy system. We hope we can compare these two methods in several terms and publish the results soon after competitions.

- **Positioning**

Finding a solution to select the best position to pass the ball to another player has been one of the challenges in humanoid soccer robots. To solve this problem, we have developed a positioning algorithm using a fuzzy system to select that position. The fuzzy system can find a good position based on the attacker's current position and the best free point in the occupancy grid map. The new approach however still needs further optimizations but early tests has proven that it is a successful system and will be as the backbone of the strategy in our future behavior plans.

3 Conclusion

In this paper we have presented the specifications of the hardware and software of MRL kidsize humanoid robot system developed under the RoboCup 2014 rules. MRL commits to participate in RoboCup 2014 in João Pessoa, Brazil with further enhanced hardware and software based on the achievements of previous year and we also commit to introduce a referee familiar with the rules of the Humanoid League. We use DARwIn-OP as our base platform and we are working on this platform with about totally 20 graduate and undergraduate students modifying and optimizing the platform in vision, motion control, world modeling, self-localization, behavior, and embedded control board as is discussed in the related sections. Up to now we have 9 published and 3 submitted papers in the related research fields.

References

[1] DARwIN OP, http://www.romela.org/main/DARwIn_OP:_Open_Platform_ Humanoid_Robot_for_Research_and_Education, retrieved Jan 2013.
[2] Upenn RoboCup: Code, available online: https://fling.seas.upenn.edu/~robocup/ wiki/index.php?n=Main.Code, retrieved Jan 2013.
[3] Rafael C. Gonzales and Richard E. Woods, Digital Image Processing, Prentice Hall, 2001.

[4] Mojtaba Ghanbari, Reza Safdari, Ehsan Nazari, and Mostafa E. Salehi "Evaluating the Effect of Intensity Variations on Object Detection in Humanoid Soccer Playing Robots," *in Proceedings the 2013 RSI International Conference on Robotics and Mechatronics (ICROM 2013), in press,* 13 -15 Feb 2013.
[5] M. Sridharan and P. Stone, "Autonomous Planned Color Learning on a Mobile Robot Without Labeled Data," *in Proc. of ICARCV,* pp.1-6, 2006.
[6] Reza Safdari, Reza Kashkoee, M. Reza Najafipour, Mostafa E. Salehi, "Minimizing cognition cost using conditional vision for humanoid soccer robot," 3rd Joint Conference of AI & Robotics and 5th RoboCup Iran Open International Symposium (RIOS), 2013.
[7] Bahareh Foroughi, Reza Safdari, Reza Kashkoee, and Mostafa E. Salehi" Action Selection Using Co-Operative Occupancy Grid Map for Humanoid Soccer Robot", submitted to the 22nd Iranian Conference on Electrical Engineering ICEE 2014.
[8] J. Bresenham, "Algorithm for computer control of a digital plotter," IBM Systems Journal,
[9] Wei Hong, Changjiu Zhou and Yantao Tian, Robust Monte Carlo Localization For Humanoid Soccer Robot, *IEEE/ASME International Conference on Advanced Intelligent Mechatronics,* 2009.
vol. 4, no. 1, pp. 25–30, 1965.
[10] Sven Behnke and Jorg Stuckler, "Hierarchical reactive control for a team of humanoid soccer robots," *IEEE-RAS International Conference on Humanoid Robots,* pp. 622-629, 2007.
[11] Wu Xianxiang, Ming Yan and Wang Juan, "An improved Path Planning Approach Based on Particle Swarm Optimization," *Hybrid Intelligent Systems (HIS),* pp. 157-161, 2011.
[12] R. Shakiba, M. Najafipour, and M. E. Salehi, "An improved PSO-based path planning algorithm for humanoid soccer playing robots," in AI & Robotics and 5th RoboCup Iran Open International Symposium (RIOS), 2013 3rd Joint Conference of, 2013, pp. 1-6.