Robo-Erectus Jr-2012 KidSize Team Description Paper.

Buck Sin Ng, Carlos A. Acosta Calderon and Changjiu Zhou.

Advanced Robotics and Intelligent Control Centre,
Singapore Polytechnic, 500 Dover Road, 139651, Singapore
Email: Buck@sp.edu.sg, CarlosAcosta@sp.edu.sg, ZhouCJ@sp.edu.sg
www.robo-erectus.org

Abstract

This paper provides a brief description of Robo-Erectus Jr-2012 that is set to participate in the KidSize category in the Humanoid League of Robocup 2012. Robo-Erectus Jr-2012 is the latest version of humanoid developed in the Advanced Robotics and Intelligent Control Centre of Singapore Polytechnic.

1 Introduction

The Robo-Erectus project (www.robo-erectus.org) started as early as 2002 in the Advanced Robotics and Intelligent Control Centre (ARICC) of Singapore Polytechnic and has been active in the field of Humanoid research and developments since. The aim of the Robo-Erectus team is to develop a humanoid platform that can be used for research and education [1].

Robo-Erectus is one of the pioneer soccer-playing humanoid robots in the RoboCup Humanoid League, having participated in Robocup 2002 Fukuoka when the league first begins. Robo-Erectus came in 2^{nd} place in the Humanoid Walk competition in Robocup 2002 and 1^{st} place in the Humanoid Free Performance competition in Robocup 2003. In 2004, Robo-Erectus won the 2^{nd} place in Humanoid Walk, Penalty Kick, and Free Performance. In 2007, it finished 6^{th} on the 2 vs 2 games, and 3^{rd} on the technical challenge. In 2010 and 2011, Robo-Erectus managed to pass to the second round robin stage in the competition.

This paper is organized as follows. In Section 2, the mechanical and electrical designs are presented. Following, the motion control system, image processing and robot behavioral control system are described respectively. In Section 4, the concluding remarks are presented. Finally, a statement of commitment for the RoboCup 2012 is presented in Section 5.

2 Hardware Design

2.1 Mechanical Design

Figure 1 shows the design of the humanoid robot REJr-2012 (codename Bv-Mk2). The robot is constructed using customized aluminum brackets to provide

Fig. 1. REJr-2012, the latest version Robo-Erectus KidSize.

the necessary structural support without comprising on the robustness, the mechanical structure is similar to that of the REJr-2011, only minor modifications to brackets were made. REJr-2012 adopts a polygon link structure in the leg that increases the number of joints but simplifies the locomotion manipulability (See Table 1).

Robo-Erectus Junior has a total of 22 degrees of freedom; 14 in the legs, 6 in the arms and 2 in the head. Table 2 describes the associated degrees of freedom. Each degree of freedom is actuated by a *Kondo Digital Servomotor*; the upper body employs the Kondo KRS-4014 S-HV and lower body employs the Kondo KRS-6003 HV servomotor. Table 3 provides the servomotor's specifications.

Table 1. Physical Specifications of the REJr-2012.

Weight	Dimensions			Speed	
	Height	Width	Depth	Walking	Running
4.4kg	560mm	240mm	120mm	30cm/sec	50cm/sec

Table 2. List of Degrees of Freedom for the humanoid robot REJr-2012.

Body Part	Roll	Pitch	Yaw
Head		✓	✓
Shoulder	✓	✓	
Elbow		✓	
Hip	✓	✓	✓
Knee		✓	
Ankle	✓	✓	

Table 3. Specifications of the actuator.

Actuator	Torque	Speed
KRS-4014 S-HV	40.8 kg.cm @ 10.8v	0.19 sec / 60 deg @ 10.8v
KRS-6003 HV	67.0 kg.cm @ 11.1v	0.22 sec / 60 deg @ 11.1v

2.2 Electrical Design

Figure 2 shows the electrical architecture of the Robo-Erectus Junior. Robo-Erectus Junior adopts a decentralized system in which the task are sub-divided and assigned to two level of processors; high level host processor and low level micro-processor. Table 4 shows the specification of these processors.

1. The high level host processor consist of a single main processors that processes and coordinates behavioral aspect of the robot. High complexity or computational demanding task such as image processing and behavioral control are handled by the host processor.
2. The low level micro-processor handles task that requires real-time handling. These task include motion control, sensor feedback and communication with the main processor.

Robo-Erectus Junior is equipped with four type of sensors. Table 5 shows the specifications of the sensors employed.

1. An USB camera running at 30 frame per second to capture images is connected to the host processor.
2. An inertia measurement unit *IMU*, consisting of 2-axis gyros and 3-axis accelerometers, is used to measure the tilt of the robot during play.
3. A rated gyro is connected to the micro-processor to give orientation information during the absence of localization information from the camera.

Table 4. Specifications of the processors

Features	High Level Host Processor	Low Level Micro-Processor
Processor	fitPC	dsPIC
Speed	2000Mhz	80Mhz

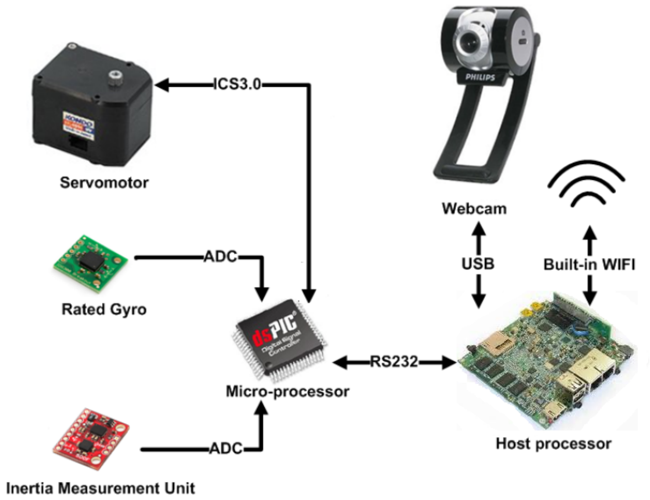

Fig. 2. Robo-Erectus Architecture

4. Each servomotor is embedded with a positioning sensor to provide angular positions feedback for each joints.

Communication between the host processor and micro-processor utilizes the standard RS232 serial link. For communication with its teammate, Robo-Erectus Junior uses a wireless network. The host processor has a built-in WIFI module that allows information exchange to and from the robot.

Robo-Erectus Junior is powered using a single 3-cells high-current Lithium polymer rechargeable battery which allows 15-20 minutes of operation. The battery is encase in the body with proper fail-safe electronics for safety and protection.

Table 5. Specifications of the sensors

Sensor	Details
Camera	640x480 Resolution 30fps.
Gyro (IMU)	$\pm 500^{\circ}/sec$ angular rate.
Accelerometer(IMU)	$\pm 3g$
Rate Gyro	$\pm 300^{\circ}/sec$ angular rate

3 Software Specifications

3.1 Motion Control

Robo-Erectus Junior employs *Estimation of Distribution Algorithm EDA* [2, 3] and *Factorized Distribution Algorithm FDA* based gait optimization method to generate biped gaits that satisfy a criterion. The EDA speeds up the searching in a highly dimensional coupling space constructed by the permutation of the optimization parameters to establish a periodic orbit in biped locomotion whereas the FDA, based on the maximum entropy principle, helps to better understand how information are transferred between these parameters [4].

This year, to increase the robustness of the Robo-Erectus Junior's locomotion, an approach using neural oscillator as Central Pattern Generator for a biped robot locomotion [5] with compliance control [6] was implemented. Simulations show that this approach helps the robot achieve better stability in walking.

3.2 Image Processing

The computer vision software on-board Robo-Erectus Junior detects the ball, the goals, the corner poles, field lines and other players using the YUV color space. A predefined look-up table segments the image obtained from the camera in the YUV range for object recognition.

Segmentation of the image is performed using scan lines that are distributed across the image to reduce the processing time. A characteristic series of color or pattern of color segments is an indication of an object of interest.

Following in a multistage process, relevant colored objects are detected (See Fig. 3) and important features(lines, landmarks, and the ball) are recognized [7]. The position of each object is estimated to an egocentric frame and merged with previous observations to yield a robust egocentric world presentation. A motion model is used to adjust the observation when the robot is moving.

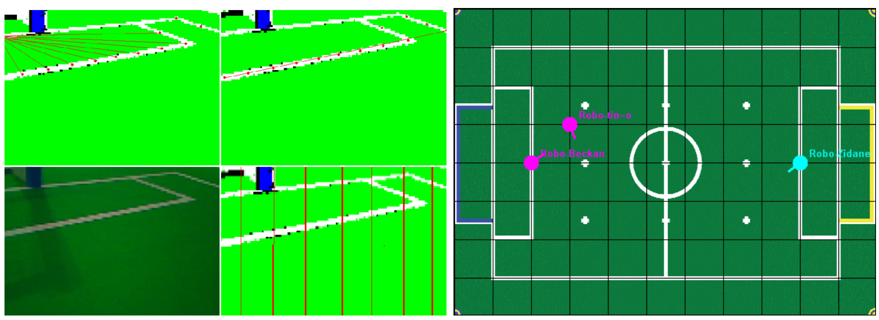

Fig. 3. The image processing

3.3 Behavior Control

The behavior control module, consisting of a framework of *hierarchical reactive behaviors*, provides the functioning of the robot in autonomous mode. This structure restricts interactions between the system variables and thus reduces the complexity [8, 7]. The control of the behaviors happens in three layers: skill, reactive, and planning layer.

The skill layer controls the servo, monitors targets, actual positions, and motor duties. The skill layer translate actions from the reactive layer into motor commands and feedback to the reactive layer once the commands are executed.

The reactive layer implements the robot behaviors like walking, kicking, getting-up, and so forth. This layer selects the behaviors based on the desire task that the planning layer send. Corrections behaviors required due to deviation from actual task is also handled by this layer.

The planning layer use the behaviors of the reactive layer to implement soccer skills such as defending and attacking behaviors. The behaviors at the planning layer are abstract goals which are passed to the reactive layer.

3.4 Dynamic Role Assignation

In a robot soccer game, the environment is highly competitive and dynamic. The proposed approach conceived the team as a self-organizing strategy-based decision making system, in which the robots are able to perform a dynamic switching of roles in the soccer game. The changing of roles will be filtered based on three criteria; Strategy, Game Time and Goal Difference respectively [9].

1. Strategy, the strategy to be used for the game will be selected before kick-off and half time of the game. The strategy defines the final objective of the team, and specifies if team should be more offensive or defensive in their play.
2. Game Time, the time of the game, 10 minutes for each half of the normal game, and 5 minutes for each half of extra time when required.
3. Goal Difference, defined as the difference of own team goal score and opponent team goal score.

At several points during the robot soccer game, the robots need to communicate with one another. This may involve informing agents of events or responses, asking for help or information, and negotiating to iron out inconsistencies in information or to agree on a course of action. Negotiation will be necessary when changing of roles is required. In review of the dynamic roles design, the ball approach method should be taken into consideration. Team formation change may be based on the positions of the three robots. This could be useful when two robots required negotiating for a particular role. The proximity and approach to the ball could be used to determine which robot would get the role. Besides, the ball approaching and ball possession is important to coordinate the robots during the game. During a game there could be situations where a team must play with substitute robots, and occasionally the team must play with fewer

Fig. 4. Ball approaching and team coordination during RoboCup2011 games.

players. To deal with these situations, the proposed formations roles with priorities. These priorities indicate which roles must be filled first. Figure 4 presents

Table 6. Formations and priorities of the roles per formation.

Formation	Highest	High	Low
Defensive	Goalie	Defender	Defender
Normal	Goalie	Defender	Striker
Offensive	Goalie	Striker	Striker
Super Offensive	Defender	Striker	Striker
All Out	Striker	Striker	Striker

the approach to ball and team coordination with two robots. Since both robots have striker role, both will try to approach the ball. However, once one striker reach the ball and takes possession of the ball, the second striker will keep a distance. This coordination has been further explore to pass the ball.

4 Conclusion

In this paper, we introduced the state-of-art of the Robo-Erectus Jr-2012 humanoid robot. In compare to its predecessors, the latest version of the Robo-Erectus has significant improvements to its speed, stability and reliability and is prepared for the Robocup 2012 competition. For more detailed information about the Robo-Erectus, please refer to the team's website www.robo-erectus.org.

5 Statement of Commitment

Our Team Robo-Erectus is committed to take part in the Humanoid League, KidSize category, at the RoboCup 2012. Our Team consists of professional staff and students so that we can perform our best in the competition. Robo-Erectus Team commits that a member of the team will be proficient to serve as referee during the KidSize competition. The Team commits that the member that will act as referee will be able to act as main referee, assistant referee or Referee Box Controller. Robo-Erectus Team also understand the implication of failing to any of these commitments for future participation in the Humanoid League.

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