Robo-Erectus Jr-2010 KidSize Team Description Paper.

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Abstract

This paper provides a brief description of Robo-Erectus Jr-2010 that is set to participate in the KidSize category in the Humanoid League of Robocup 2010. Robo-Erectus Jr-2010 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.

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. Finally, in Section 4, the concluding remarks are presented.

2 Hardware Design

2.1 Mechanical Design

Figure 1 shows the design of the humanoid robot REJr-2010. The robot is constructed using customized aluminum brackets to provide the necessary structural

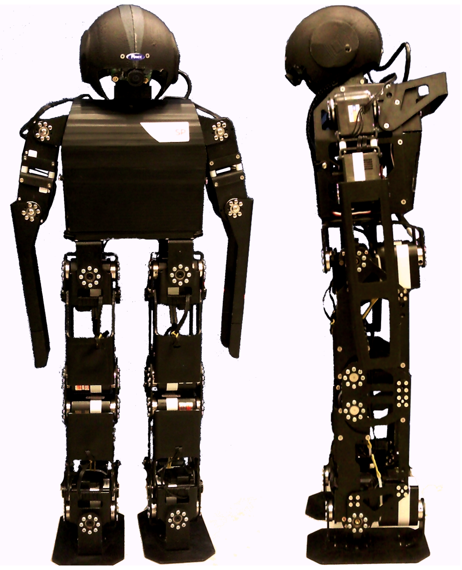

Fig. 1. REJr-2010, the latest version Robo-Erectus KidSize.

support without comprising on the robustness. REJr-2010 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.

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

Table 1. Physical Specifications of the REJr-2010.

Weight	Dimensions			Speed	
	Height	Width	Depth	Walking	Running
4.3kg	560mm	240mm	120mm	25cm/sec	40cm/sec

Table 2. List of Degrees of Freedom for the humanoid robot REJr-2010.

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

computational demanding task such as image processing and behavioral control are handled by the host processor.

2. The low level micro-processor is made up of two sub-processors that handle 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.
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 whereas communication within the sub-processors utilizes the serial peripheral interface. 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.

Table 4. Specifications of the processors

Features	High Level Host Processor	Low Level Micro-Processor
Processor	Gumstix	dsPIC
Speed	500Mhz	30Mhz

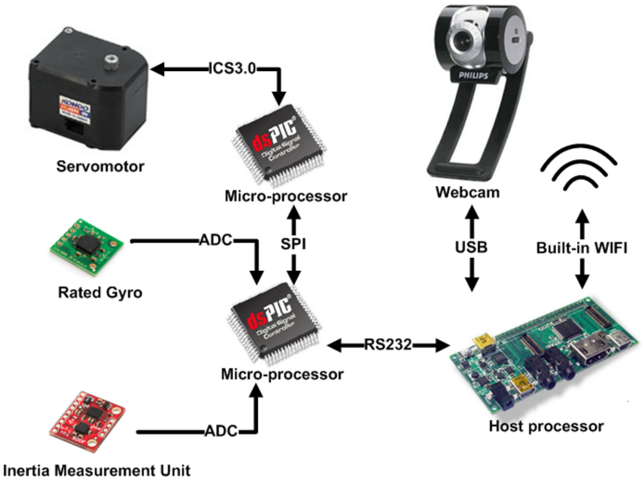

Fig. 2. Robo-Erectus Architecture

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.

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.

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

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

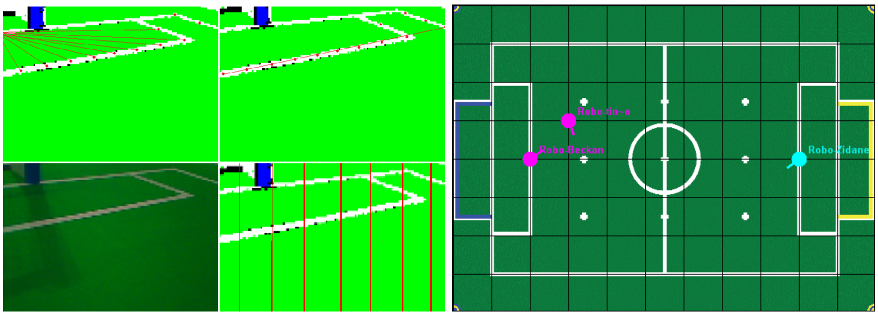

Fig. 3. The image processing

robot locomotion [4] with compliance control [5] 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. 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.

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 [6]. 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.

4 Conclusion

In this paper, we introduced the state-of-art of the Robo-Erectus Jr-2010 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 2010 competition. For more detailed information about the Robo-Erectus, please refer to the team's website www.robo-erectus.org.

Acknowledgments

The authors would like to thank staff and students at the Advanced Robotics and Intelligent Control Centre (ARICC) and higher management of Singapore Polytechnic for their support in the development of our humanoid robots.

References

1. C. Zhou and P.K. Yue. Robo-Erectus: A low cost autonomous humanoid soccer robot. *Advanced Robotics*, 18(7):717–720, 2004.
2. L. Hu, C. Zhou, and Z. Sun. Estimating probability distribution with Q-learning for biped gait generation and optimization. In *Proc. of IEEE Int. Conf. on Intelligent Robots and Systems*, 2006.
3. L. Hu, C. Zhou, and Z. Sun. Hybrid estimation of distribution algorithm with application to biped gait generation. *Information Sciences*, 2006.
4. Carlos Antonio Acosta Calderon, Rajesh Elara Mohan, and Changjiu Zhou. Rhythmic locomotion control of humanoid robot. In *MICAI 2008: Advances in Artificial Intelligence*, volume 5317/2008, pages 626–635, Oct 2008.
5. Masaki Ogino, Hiroyuki Toyama, Sawa Fuke, Norbert Michael Mayer, Ayako Watanabe, and Minoru Asada. Compliance control for biped walking on rough terrain. In *RoboCup 2007: Robot Soccer World Cup XI*, volume 5001/2008, pages 556–563, July 2008.
6. Carlos Antonio Acosta Calderon, Changjiu Zhou, Pik Kong Yue, Mike Wong, and Mohan Rajesh Elara. A distributed embedded control architecture for humanoid soccer robots. In *Proc. of Advances in Climbing and Walking Robots*, pages 487–496, Singapore, July 2007.