Robo-Erectus Senior III (RESr-III): A Teen Size Humanoid Soccer Robot

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Abstract. This paper provides a brief description of Robo-Erectus Senior III– a teen size soccer playing humanoid robot developed at Advanced Robotics and Intelligent Control Centre of Singapore Polytechnic. The mechanical and electrical specifications of the robot are described. This paper also covers the vision processing, locomotion control, state-driven Monte Carlo localization and force/torque sensors ZMP detection of Robo-Erectus Senior III. This robot is used as a platform for competing in RoboCup humanoid league, and for our ongoing research in humanoid robot localization and navigation.

1 Introduction

Robo-Erectus Senior (RESr-III) is a full-size humanoid robot developed by the Advanced Robotics and Intelligent Control Centre (ARICC), Singapore Polytechnic. The objective of the RESr project is to develop a humanoid robot with more human-like features and human-friendly character. The design concepts of RESr-III includes modular development, compact design and emphasis on the robot's ability to perform cooperative works in general and soccer (RoboCup) in particular [1, 2, 3] (www.robo-erectus.org).

RESr-I gave an outstanding exhibition in the Humanoid League of RoboCup2007 and won the 4th place in the penalty kick competition of Humanoid TeenSize League. It was also featured in CNN Live. The Robo-Erectus project has been initiated since 2002. It has 3 categories: (1) RE Junior for educational purpose; (2) RE Junior for Humanoid KidSize competition; (3) RE Senior for Humanoid TeenSize competition and also for research on full-size humanoid robotics. RESr-III is also incorporated into our R&D framework using Microsoft Robotics Studio. Force/torque control is also studied by installing ATI Force/Torque sensors Nano25 and Mini85 on the ankles of the humanoid robot REJr and RESr-III respectively [4].

Brief description on the hardware and software specifications of RESr-III is presented in the following sections.

2 Hardware of Robo-Erectus Senior

2.1 Mechanical Structure of Robo-Erectus Senior

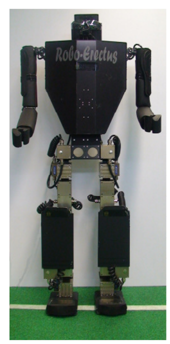
Table 1. Mechanical and electrical parameters of RESr-III

1. Physical Specifications

Weight	Dimensions			Speed	
	Height	Width	Depth	Walking	Running
44kg	140cm	28cm	20cm	5m/min	---

2. Degrees of Freedom

Joint	Roll	Pitch	Yaw
Head			✓
Shoulder	✓	✓	
Elbow		✓	
Hip	✓	✓	✓
Knee		✓	
Ankle	✓	✓	



3. Sensors

Sensor	Details
Camera	320×240 Resolution 30fps
Compass	1° heading accuracy
Tilt	6 dimensions
Sonar	Distance range 5cm-250cm

4. Computing Unit

Features	Main Processor	Vision	Sensor/Actuator
Processor	Intel Celeron	Intel Core Solo	Dual PIC18F8720
Speed	800MHz	1.33GHz	25MHz
Memory	1GB	1GB	8KB
Storage	30GB	16GB	256KB
Interface	CAN BUS, USB, WIFI	USB, WIFI	RS232, RS485

Modular design concept is employed in the development of RESr-III. The modular biped robot system consists of a set of independently designed modules, such as actuators, passive joints, rigid links (connectors) that can be rapidly assembled into a complete robot of various configurations having different kinematics and dynamic characteristics.

Final dimensional parameters of RESr-III after repeated experiments and optimization are given in Table 1. It has 22 Degrees Of Freedom (DOFs). The joints are powered by rechargeable lithium-polymer battery matrix that can support biped walking for half an hour. The robot is controlled by a single board computer and a Sony VAIO ultra portable PC, which are in charge of robot navigation and localization and vision processing respectively.

2.2 Electrical Control Structure of Robo-Erectus Senior

The active modules of the robot are self-contained mechatronic units with the control loop closed at the joint level. Each actuator module has its own individual motion controller. The inter-module communication is implemented using the CAN-bus protocol and the RS-485 serial interface. Low level trajectory generation and control are developed based on hierarchical control concept.

Besides visual sensor, tilt sensor and an electronic compass is installed in upper body to get the tilt information and to measure the moving direction. The block diagram for locomotion control and vision administration is shown in Fig. 1.

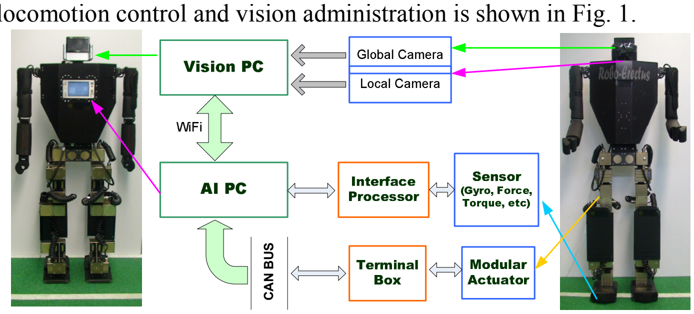


Fig. 1. Block diagram for RESr-III hardware control.

3 Biped Gaits Synthesis for Robo-Erectus Senior

3.1 Gait Generation and EDA Offline Gait Optimization

Biped walking is represented by three key poses extracted from one cycle. Poses between these key poses are approximated by third order spline functions. A technique of this type has been implemented using splines of class C^2. Basic gait pattern of walking, turning and kicking as required in soccer game is planned in a simple and an efficient way. It provides an easy way to operate the robot with simple mathematical form and smooth locomotion properties.

All these locomotion are generated following strict formulations. Further optimization via Estimation of Distribution Algorithm is given in [3].

For the simplified robot model with geometric and state constraints, searching for proper joint degree sequence would require the computation of a discrete-time map from R^{N_q} to R^{N_q}, which is hard for analysis. So we transfer the joint degree searching in infinite dimensional space to probability distribution space modeling by finite vectors with EDA. EDAs can successfully generate expected biped gaits that minimize the predefined objective function in short learning iterations.

3.2 Markov Chain and Action Primitive for Online Gait Generation

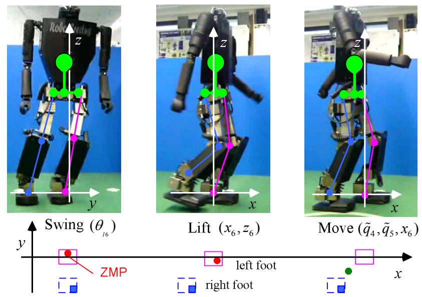


Fig. 2. The three action primitives defined in biped walking

Unlike offline gait generation and optimization approaches, gaits are not generated by organizing the joint movement or with the distribution of actuated torques in online gait generation. Not gaits but three action primitives as Swing, Lift and Move (see Fig.2) are stored online. Gaits are constructed by candidate poses using Markov chain.

4 The state-driven Monte Carlo localization

4.1 Feature variables

Two feature variables, 'focus' and 'near', are associated with the sample set at each time. Focus is a Boolean variable created based on the concept of an occupied rectangle region $\mathrm{R}(L,W)$. Focus can be updated periodically according to

$$focus = \begin{cases} \mathrm{Y} & \text{if } \mathrm{R}(L,W) \le \mathrm{R}(L_{thres}, W_{thres}) \\ \mathrm{N} & otherwise \end{cases} \tag{1}$$

Feature variable 'near' is given to express whether the real position is reached.

$$near = \begin{cases} +1 & if\ |d - d_k| \le d_{thres}\ and\ |\theta - \theta_k| \le \theta_{thres} \\ 0 & if \text{ the token is not detected} \\ \text{-}1 & if\ |d - d_k| > d_{thres}\ or\ |\theta - \theta_k| > \theta_{thres} \end{cases} \tag{2}$$

where d_{thres} *and* θ_{thres} are threshold values in the distance and direction.

Focus and near can be considered to estimate the state of particles from intrinsic structure and extrinsic sensor information respectively.

4.2 State Identification and Successive Action

During the process of filtering, the states of particles are divided into four kinds: messy, approach, cluster and error, which are determined by the combination of the values of the two feature variables mentioned above.

4.3 Experimental Results

Interface for Physical experiment is shown in Fig. 3.

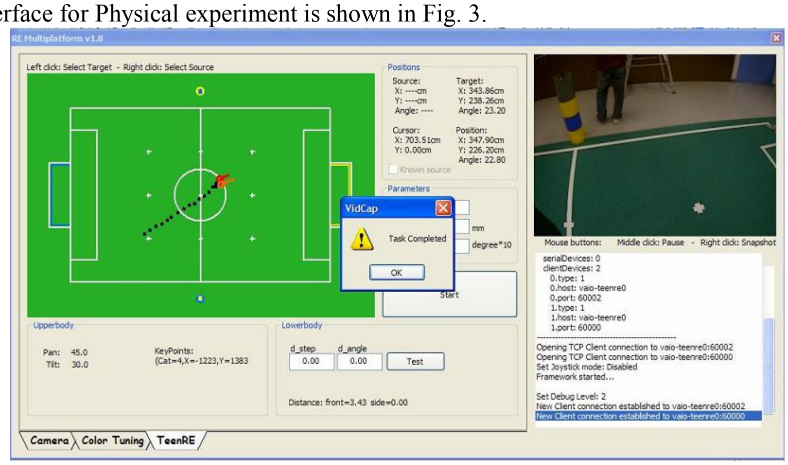


Fig. 3. Interface of physical experiment.

The physical experiment result is shown in Fig. 4.

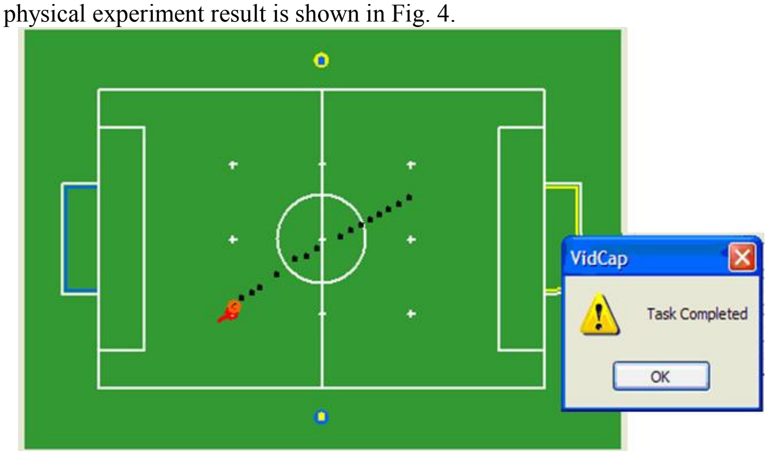


Fig. 4. Result of localization experiment result.

5 Vision Detection and Recognition

Fig.5 shows the raw images and the processed results of the processing system [5, 6].

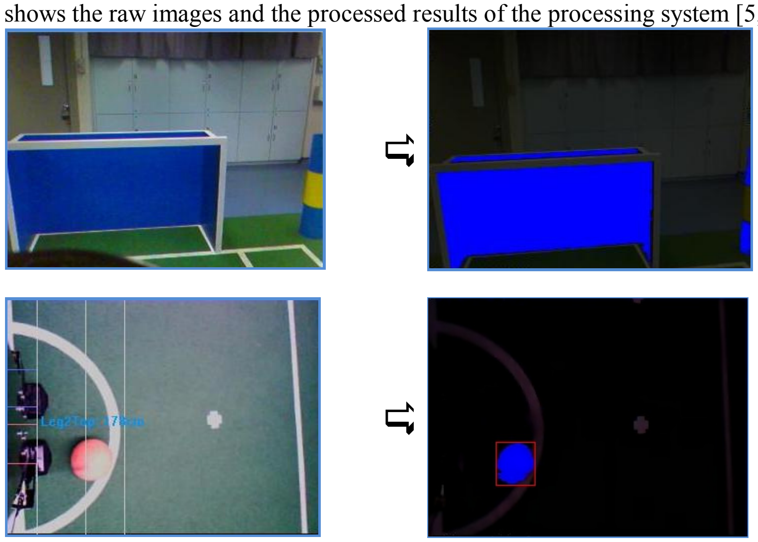


Fig. 5. Object detection in vision processing.

6 Force/Torque Sensor for ZMP Control

ATI Mini85 Force/Torque sensors are installed in the ankles of RESr-III (Fig. 6) and the ZMP detection research has been performed (Fig. 7).

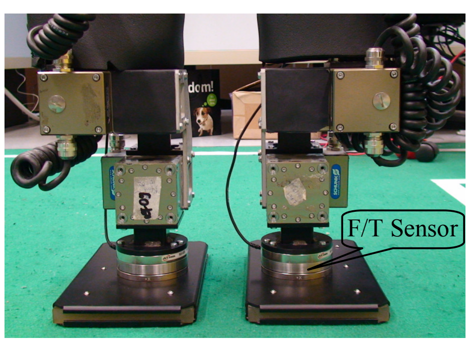


Fig. 6. Force/Torque sensors in the ankles.

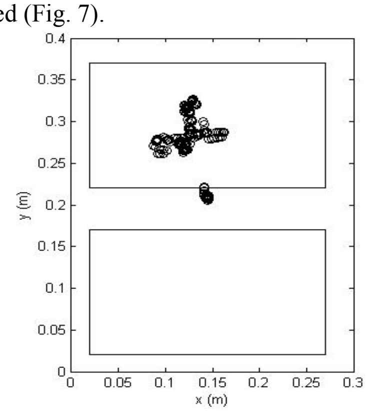


Fig. 7. ZMP distribution in kicking motion.

7 Team Information

Robo-Erectus team is formed by about twenty robot enthusiasts coming from eight countries. Their hard works are expected to make it possible for RESr-III to put up an outstanding show in the coming RoboCup 2009. Their information is as follows.

Team Leader:	Changjiu Zhou
Operation Manager:	Rajesh Elara Mohan
Robo-Erectus Junior Captain:	Dr Carlos Antonio Acosta Calderon
Robo-Erectus Senior Captain:	Pik Kong Yue
Team Member:	Liandong Zhang
	Tianwu Yang
	Wei Hong
	Guohua Yu
	Nguyen The Loan
	Hendra
	Jhohan Ng
	Sudirman
	Peter Zhaoyuan Lin
	Zhiwei Song
	Peijie Zhang

8 Conclusion

The Robo-Erectus Senior project aims to develop a platform for competing in RoboCup Humanoid Teen Size League and for our ongoing research work in humanoid robot localization and navigation areas. As a part our research, we have developed simulation software using Microsoft Robotics Studio for the study and analysis of humanoid gait generation and optimization. A Linux OS based object oriented software framework is implemented for object recognition, motion control and communication to achieve real time capabilities in terms of robot localization and navigation. A state-driven Monte Carlo localization method has been developed and has been verified by experiments. Force/Torque sensors are installed in the RESr-III and the ZMP is measured. During the experiments conducted, Robo-Erectus Senior exhibited excellent walking and soccer skills. For more detailed information about Robo-Erectus humanoid soccer robots, please refer to the team's website www.robo-erectus.org.

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