Robo-Erectus: A Soccer-Playing Humanoid Robot

Changjiu Zhou[1], Pik Kong Yue[1], Fook Seng Choy[2], Nazeer Ahmed[1]

[1]School of Electrical and Electronic Engineering,
Singapore Polytechnic, 500 Dover Road, Singapore 139651
[2]School of Mechanical and Manufacturing Engineering,
Singapore Polytechnic, 500 Dover Road, Singapore 139651
{ZhouCJ,yue,FookSeng,nazeer}@sp.edu.sg
http://www.robo-erectus.org

Abstract. This paper provides a brief description of a low-cost soccer-playing humanoid robot Robo-Erectus (RE) developed at Singapore Polytechnic. We had participated in the Humanoid League 2002 being held for the first in history, and won second place for the Humanoid Walk competition. To develop a low-cost humanoid platform which is affordable for many researchers, our RE humanoid robots have been intentionally designed to have low-torque servo motors and low-precision mechanical structures so that the cost can be significantly reduced. Inspired by human's remarkable capability of utilizing perceptions, we conduct a research aimed at synthesizing humanoid gaits through the incorporation of both perception-based and measurement-based information. For this reason, a fuzzy reinforcement learning (FRL) agent has been developed to implement perception-based humanoid walking and kicking pattern generation for the Robo-Erectus.

1 Introduction

Humanoid soccer robot league is a new international initiative to foster robotics and AI technologies using soccer games [1]. The humanoid league is more challenging than any existing wheeled or multi-legged robotic soccer game because the dynamic stability of humanoids needs to be well maintained while the robots are walking, running, kicking and performing other tasks. Furthermore, soccer-playing humanoid robots will have to handle the ball with both feet and hands, and be robust enough to deal with challenges from other players.

Humanoid gait generation and adaptation have their own challenges. Since the information available for humanoid gait synthesis is a mixture of measurements and perceptions, a neural fuzzy system with unique capabilities of dealing with both numerical data and linguistic information is a naturally good choice. For this reason, a fuzzy reinforcement learning (FRL) agent [3, 4] with a neuro-fuzzy architecture is selected to demonstrate how the perception-based information can be incorporated in the FRL agent to initialize its action network, critic network and evaluation feedback module so as to improve humanoid gaits by learning.

This paper is organized as follows. The soccer-playing humanoid platform developed at Singapore Polytechnic is introduced in Section 2. In Section 3, we describe the control and learning issues for the Robo-Erectus. Concluding remarks and some major technical challenges in this field are addressed in Section 4.

2 Configuration of Robo-Erectus

A soccer-playing humanoid should have high DOF (degree-of-freedom) to achieve various behaviors, such as locating and kicking a ball, avoiding obstacles, shooting or passing the ball, and etc. To implement these behaviors, the following four fundamental motions are needed: (i) keeping the humanoid balance (static or dynamic stability); (ii) moving the swing leg; (iii) operating a grasping object; (iv) controlling visual attention.

To implement the above-mentioned behaviors, we have developed different types of humanoid robots named Robo-Erectus (see Table 1). The robot needs various kind of sensors, e.g. visual sensor for recognizing objects; posture sensors for detecting the robot's balance; force and tactile sensors for detecting contact to others and falling down, and so on. Our first generation soccer playing robot Robo-Ercetus, which came to second at the First RoboCup Humanoid League – Humanoid Walk, is shown in Fig. 1. The newly developed RE50II and its DOF arrangement are illustrated in Fig. 2. Fig. 3 shows a Penalty Kicking experiment conducted in our laboratory, where RE40I acts as a kicker while RE40II performs as a goal-keeper.

Table 1. Specifications of the Robo-Erectus' family

	RE40I	**RE40II**	**RE50II**	**RE80II**
Height	40 cm	40 cm	50 cm	80 cm
Weight	2.5 kg	4 kg	5 kg	7 kg
Total DOF	10	22	22	22
DOF arrange-ment	Legs – 5 x 2	Neck – 2 Arms – 4 x 2 Legs – 6 x 2	Neck – 2 Arms – 4 x 2 Legs – 6 x 2	Neck – 2 Arms – 4 x 2 Legs – 6 x 2
Sensors	accelerometers, force sensors, gyros, range sensors and etc.			
Vision	stereo camera			
Controller	Multi-control mode: (1) PC; (2) Microcontroller; (3) PDA; (4) Wireless			
Power	NiMH batteries			

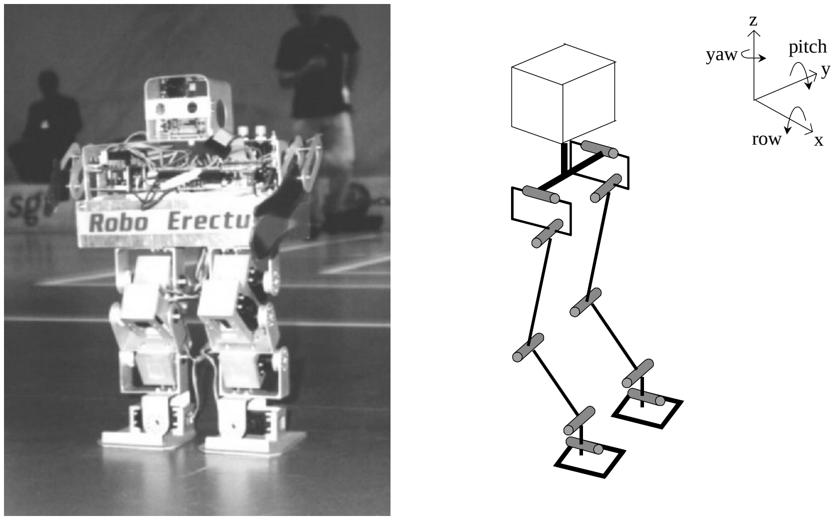

Fig. 1. The first generation Robo-Erectus at RoboCup Humanoid League 2002

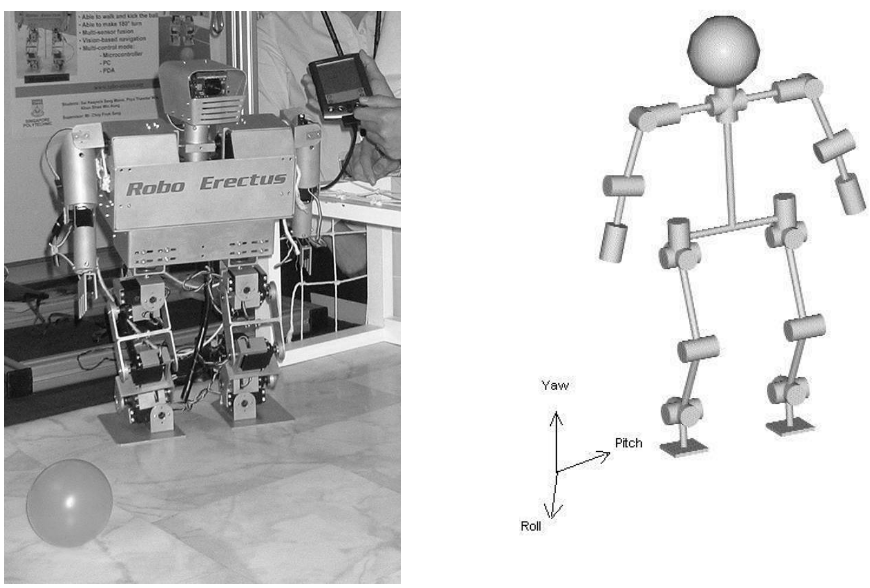

Fig. 2. The second generation Robo-Erectus RRE50II (controlled by PDA) and its DOF arrangement

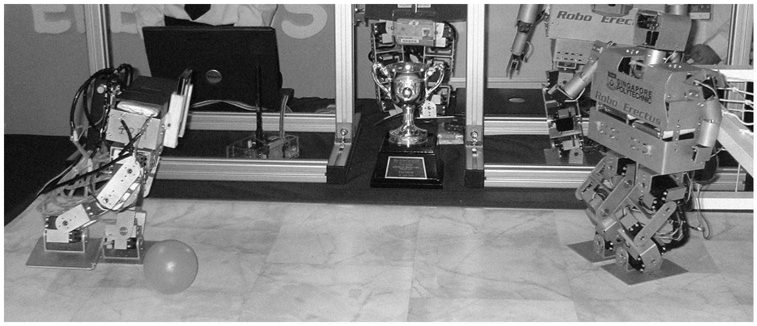

Fig. 3. Humanoid robots Robo-Erectus RE40I and RE40II (RE40I acts as a kicker while RE40II performs as a goal-keeper)

To develop a low-cost soccer-playing humanoid platform which is affordable for many researchers, we have to use low-cost components. Our RE humanoid robots have been intentionally designed to have low-torque motors and low-precision mechanical structures so that the cost can be significantly reduced. For example, the actuators of RE humanoid robots are low-cost servo motors which have limited torque and accuracy. We also note that PINO [3] used the similar design concept to achieve a low-cost humanoid platform.

3 Basic Control and Learning Issues for Robo-Erectus

The overview of the proposed hierarchical control system for humanoid robots is shown in Fig. 4. The path planning level deals with path planning, obstacle crossing and gait selection using high level sensorial information. The gait synthesizer receives gait phases, step length, speed and lift magnitude from the path planning level, and then repetitively generates the joints reference commands for each control cycle during each gait phase.

In order to reduce the complexity of the humanoid gait synthesis problem, many researchers assume that the gait synthesis in the sagittal and frontal planes is independent. Therefore, as shown in Fig. 5, there are two FRL agents, namely, FRL Agent-x and FRL Agent-y for sagittal and frontal planes respectively. Each FRL agent only searches its relevant state-action space so as to speed up learning. The FRL architecture and its learning method can be found in [3, 4].

Humans usually evaluate their walking behavior in a heuristic way. For example, to evaluate humanoid dynamic balance in the sagittal plane, a penalty signal r_x should be given if the humanoid robot falls down in the same plane, that is, x_{zmp} is not within the supporting area in the sagittal plane. However, this kind of two-value evaluative feedback signals can only describe the simple “go – no go” or “fall down – stand” walking states. It is surely not biologically plausible. To provide more detailed information on evaluative feedback, we may use our perceptions to evaluate the humanoid dynamic walking.

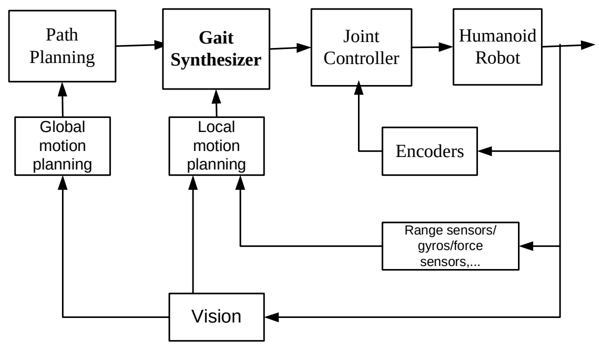

Fig. 4. Schematic diagram of the hierarchical control system for the humanoid robot

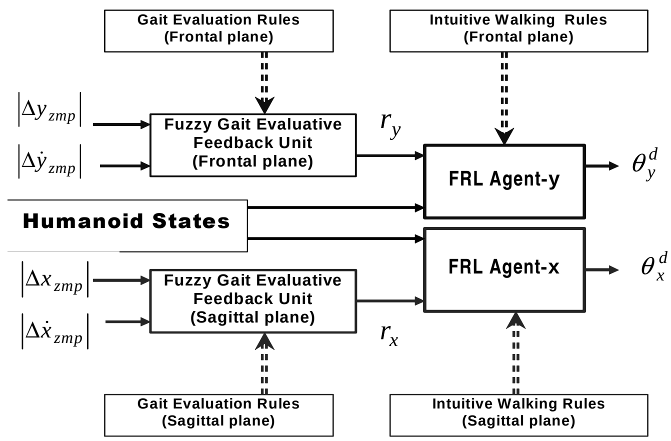

Fig. 5. Block diagram of the humanoid gait synthesizer using two independent FRL agents

4 Concluding Remarks

In this section, we demonstrate how to utilize perception-based information for gait generation and adaptation of humanoid robots. Two experiments, namely, Humanoid Walk (see Fig. 6) and Penalty Kick (Fig. 7), which are the major tasks that soccer-playing humanoid robots have to perform at Humanoid League, have been conducted.

Humans do not just learn a task by trial and error, rather they observe other people perform a similar task and then repeat them by *perceptions*. How to utilize perception-based information to assist humanoid imitation learning will be a new challenge in this filed .

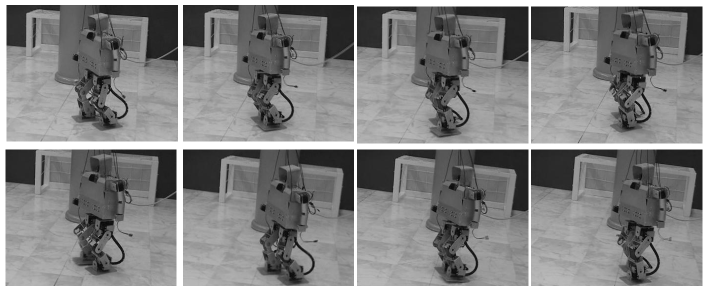

Fig. 6. The humanoid walking sequence (after learning)

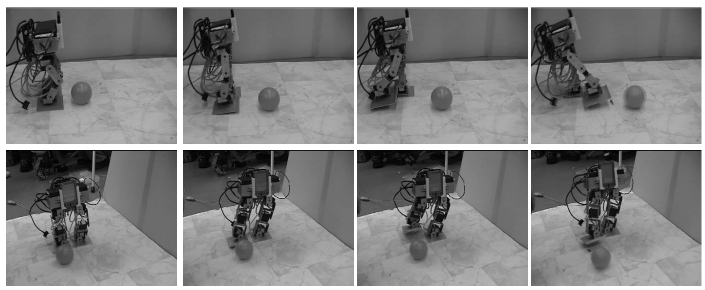

Fig. 7. The humanoid kicking sequence

Acknowledgments

The authors would like to thank staff and students at the Advanced Robotics and Intelligent Control Center (ARICC) of Singapore Polytechnic for their support in the development of our humanoid robots Robo Erectus. The research described in this paper was made possible by the jointly support of the Singapore Tote Fund and the Singapore Polytechnic R&D Fund.

References

1. Kitano H., Asada, H.: The RoboCup humanoid challenge as the millennium challenge for advanced robotics, Advanced Robotics 13(8) (2000) 723-736
2. Yamasaki, F., Matsui, T., Miyashita, T., Kitano, H.: PINO The humanoid that walk, Proc. the First IEEE-RAS Int. Conf. on Humanoid Robots, CD-ROM, 2000.
3. Zhou, C.: Robot learning with GA-based fuzzy reinforcement learning agents, Information Sciences 145 (2002) 45-68
4. Zhou, C., Meng, Q.: Dynamic balance of a biped robot using fuzzy reinforcement learning agents, Fuzzy Sets and Systems 134(1) (2003) 169-187