Team Description Paper: HuroEvolutionAD Humanoid Robot for RoboCup 2015 Humanoid League

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Abstract. HuroEvolution^{AD} is an adult size humanoid robot that was made in National Taiwan University of Science and Technology. In this paper an adult-size humanoid robot, named HuroEvolution, is developed for the purpose of participating in the RoboCup soccer gamers. The HuroEvolution is 146 cm in height and 16.3 Kgs in weight, and it is simply configured with 18 degrees of freedom, where 10 degrees of freedoms are used for two lower limbs, two degree of freedom is used for the head camera, two 6 degrees of freedom arms are used for mataining the balance when the push recovery is applied. Each leg is designed as a parallel mechanism structure to reduce the backlash effects of gear motors, as well as to reduce the uses of gear motors. The HuroEvolution is capable of omni-walking with respect to different locomotion parameters. Moreover, a specialized turning locomotion is also generated to change the robot's heading based on a limited degrees of freedom of the leg structure. The image recognition and localization approaches are also applied for navigating the HuroEvolution to finish the match in competitions.

Keywords: adult-size humanoid robot, parallel mechanism, omni-walking.

1 Introduction

Autonomous biped humanoid robot researches are still challenging engineering problems. Developments of humanoid robots must consider complicated mechanical structure designs [1], locomotion [2], [3], localization [4] and autonomous navigation [5]. In general, it is quite challenging on the autonomy issues of locomotion and navigation for biped humanoid robots. Alternatively, the biped humanoid robot may hardly operate in completely unstructured environments with uneven terrains and unknown objects.

RoboCup is an annual competition for autonomous robot developers in academic societies. The organization committee defines standard problems in a partial known unstructured environment, and the robots have to autonomously finish the missions and challenges in the competition. Robotic soccer games are defined to simulate the competition environment is specified with a specific size which is reasonable to the robot's dimension.

The adult-size biped humanoid robot competition is one of the most challenging competitions. With the adult-size humanoid league, the robot has to finish 1 v.s. 1 match and technical challenges. Before the 2014, there are four technical challenges are Obstacle Avoidance and Dribbling, Artificial Grass Challenge. and High-Kick Challenge. But in 2015 technical challenges are changed to Push Recovery and Ball Interception. In the 1 v.s. 1 match, the ball is randomly placed behind the robot in a standard competition field. The robot must move approaching the ball, and then performs the first kick. After the first kick, the robot is then able to shoot goal. Practically, the ball and goal positions are obtained in term of recognizing specific colors of ball, size-bars and goals.

2 Mechanical Design

The HuroEvolution is an adult size autonomous humanoid robot development for the RoboCup Humanoid league. The specifications of HuroEvolution are defined according to the adult size humanoid league rule in RoboCup 2015. The HuroEvolution is designed as an 18 degree-of-freedom robot, where 10 degrees of freedom is desired for the lower limb, 2 degrees of freedom is for the yaw direction and pitch direction of the active vision sensor on the neck, and two 6 degrees of freedom arms are used for mataining the balance when the push recovery is applied. The structure of the robot is constructed from aluminum alloy. For the purpose of reducing the weight, some parts are made from polymer materials. The CAD model of the HuroEvolution is shown in Fig. 1, and Table 1 lists overall specifications.

In order to reduce the backlash effect of the gear motor and light the weight of the robot, each leg is designed as a parallel structure mechanism. The backlash effect happened when the gear train converts the high speed-low torque output from the motor into the low speed-high torque input to the joints. However, the backlash strongly affects the accuracy of the locomotion control. Therefore, in the HuroEvolution project, the parallel mechanism is proposed to reduce the effect.

Lightweight is another important issue in this project. The HuroEvolution is actuated by several servo motors. Due to the servo motor provides limited torque, parallel mechanism is implemented to simplify the structure, as well as reduce the uses of the motors. At the same time, low weight also prevents the gear chain from damaged.

Because the specifically parallel mechanism is de-signed, the knees are always moving parallelly with the hip. Therefore, HuroEvolution sacrifices the ability of the pitch rotation. It is assumed that the HuroEvolution always walks on the even field, so the lack of the pitch rotation is acceptable.

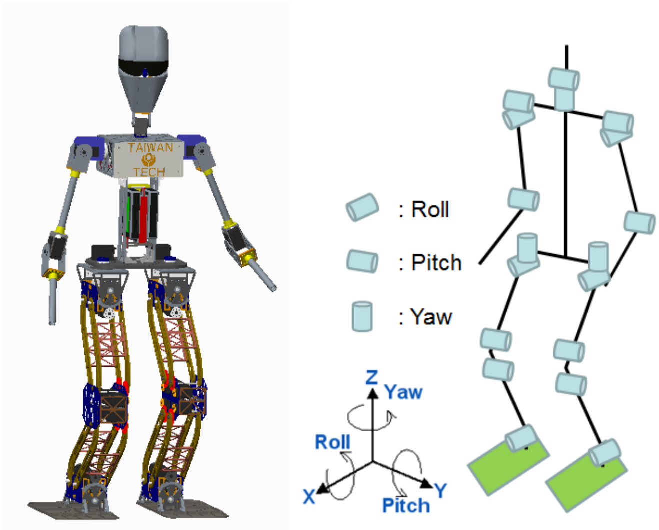

Fig. 1. CAD model (LHS) of HuroEvolution and Structure design (RHS).

Table 1. Specifications for HuroEvolution Robot.

<table>
<tr><td colspan="2">Height (cm)</td><td colspan="2">146</td></tr>
<tr><td colspan="2">Weight (kg)</td><td colspan="2">16.3</td></tr>
<tr><td rowspan="4">DOF</td><td>Leg</td><td colspan="2">10</td></tr>
<tr><td>Waist</td><td colspan="2">0</td></tr>
<tr><td>Head</td><td colspan="2">2</td></tr>
<tr><td>Arm</td><td colspan="2">6</td></tr>
<tr><td colspan="2" rowspan="2">Actuator</td><td colspan="2">Robotis MX106</td></tr>
<tr><td colspan="2">Robotis MX28</td></tr>
<tr><td colspan="2" rowspan="2">Sensor</td><td colspan="2">CCD Camera (DFM 22BUC03-ML)</td></tr>
<tr><td>Gyro Sensor Acceleration Meter</td><td>STEVAL-MKI124V1</td></tr>
<tr><td rowspan="2">Control System</td><td>Main Controller</td><td colspan="2">Pico 820 Single Board Computer</td></tr>
<tr><td>Motion Controller</td><td colspan="2">ATmega2560</td></tr>
<tr><td colspan="2">Walking Speed</td><td colspan="2">30 cm/s</td></tr>
</table>

3 Control System

In order to achieve the optimal walking trajectory and the flexible locomotion performance, the omni-walking model is proposed in this project. In this project, the trajectory of the center of the hip is generated from the linear inverted pendulum model (LIPM) [6], [7], [8]. However, in order to achieve the trajectory of locomotion planning, the end position of each foot is required. The trajectory of the swing foot is generated from cycloid curve which is indicated in (1)-(3). The locomotion parameters are shown in Fig. 2. It is noted that X_s, Y_s and Z_s are the position of the swing foot; Length, Shift and Height are the desired strike length, the shift distance and the strike height; ρ is the time percentage of the period time when the foot reaches to the highest position; Ts is the period time.

On the other hand, at the center of the hip inside the robot is equipped with a gyro sensor to sense the rotation of the hip plane [9]. According to the angular velocity, the tilt movement of the robot can be determined. In this project, a proportional-differential controller is designed to generate the compensated torque, which stabilizes the walking motion. The K-P controller is indicated in (4) and (5). It is noted that θ_{pitch} is generated from the locomotion trajectory; ω_{pitch} and ω_{roll} are the measured angular velocity.

$$x_s(t)=\frac{Length}{2\pi}\left[2\pi\frac{t}{T_s}-\sin\left(2\pi\frac{t}{T_s}\right)\right],\qquad 0\le t\le T_s \tag{1}$$

$$y_s(t)=\frac{Shift}{2\pi}\left[2\pi\frac{t}{T_s}-\sin\left(2\pi\frac{t}{T_s}\right)\right],\qquad 0\le t\le T_s \tag{2}$$

$$z_s(t)=\begin{cases}\frac{Height}{2\pi}\left[2\pi\frac{t}{\rho T_s}-\sin\left(2\pi\frac{t}{\rho T_s}\right)\right], & 0\le t\le \rho T_S\\ Height-\frac{Height}{2\pi}\left[2\pi\frac{t-\rho T_s}{(1-\rho)T_s}-\sin(2\pi)\frac{t-\rho T_s}{(1-\rho)T_s}\right], & \rho T_s<t<T_s\end{cases} \tag{3}$$

$$\theta_{outpitch}=\theta_{pitch}+\omega_{pitch}\times KP_{pitch}+\frac{d}{dt}\omega_{pitch}\times KD_{pitch} \tag{4}$$

$$\theta_{outroll}=\theta_{roll}+\omega_{roll}\times KP_{roll}+\frac{d}{dt}\omega_{roll}\times KD_{roll} \tag{5}$$

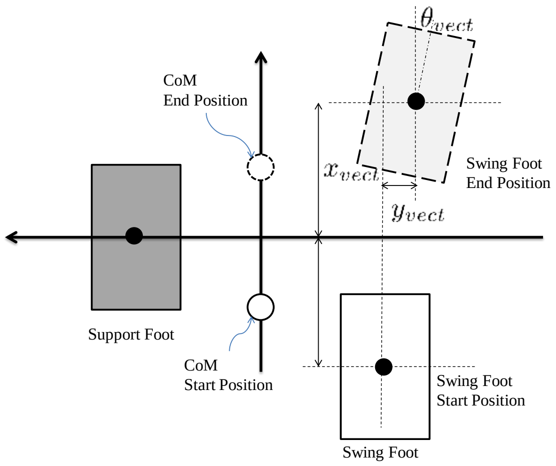

Fig. 2. The graphic symbols of the locomotion parameter.

The control system is developed to integrate the functions of locomotion control, image processing, image localization and serial communication. At the same time, a power supply and monitoring module is developed to deal with various voltage requirements of the onboard computer and gear motors, as well as to protect rechargeable batteries. An onboard computer (with type Pico-820) is selected as the supervisory controller. The onboard computer is an x86 based platform with 1.6 GHz CPU and 2GB RAM. An 8GB compact flash is acted as a file storage device which contains a reduced Windows XP operation system and a visual based reaction navigation program. The proposed control architecture is shown in Fig. 3.

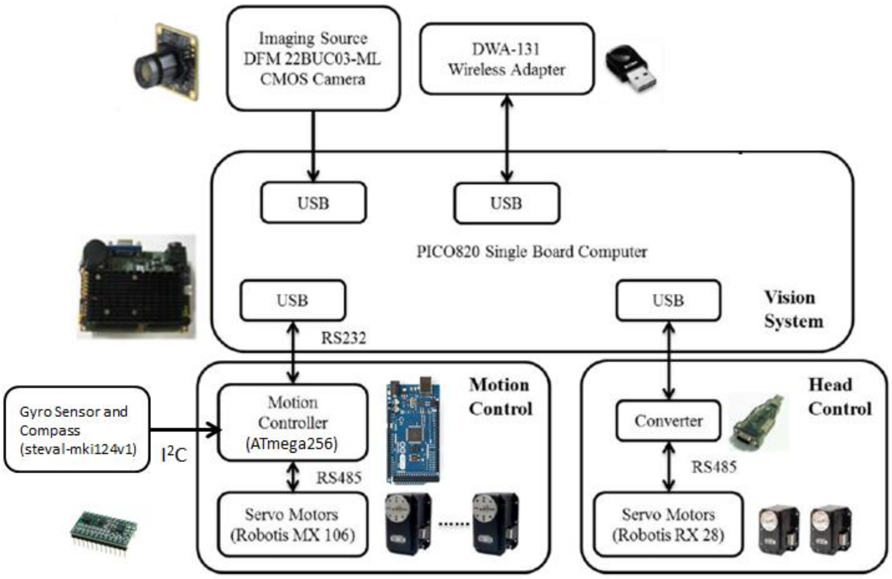

Fig. 3. Control architecture of HuroEvolution robot.

4 Conclusion

This paper presents an adult size humanoid that is specially designed to participate in RoboCup 2015. The mechanical structure design, visual guided navigation and omni-walking locomotion were all presented in this technical description paper. In this year, this robot is capable of participating in the matches of Technical Challenges and soccer games. Based on our former experience in RoboCup 2014 (as shown in Fig. 4), our robot will be able to finish the matches in this year.

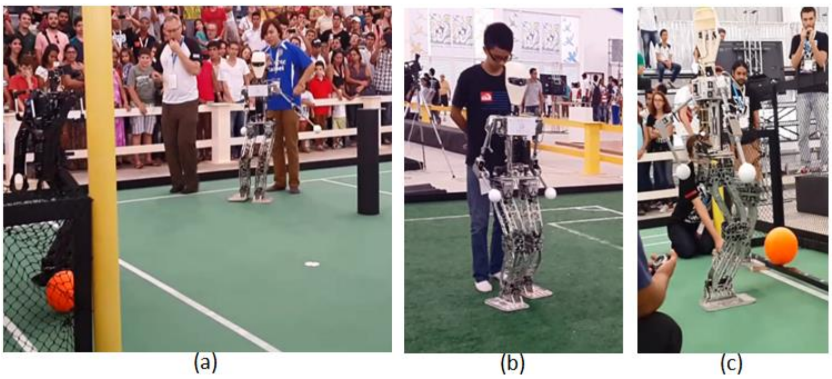

Fig. 4. RoboCup 2014: (a) The Dribble and Kick Competition. (b) Artificial Grass Challenge. (c) High-Kick Challenge.

5 References

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