

# Team Description Paper:HuroEvolutionAD Humanoid Robot for RoboCup 2013 Humanoid League

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**Abstract.** 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 149 cm in height and 15Kgs in weight, and it is simply configured with 9 degrees of freedom, where 8 degrees of freedoms are used for two lower limbs, and one degree of freedom is used for the head camera. 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 oper-

ate 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 three technical challenges. 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.

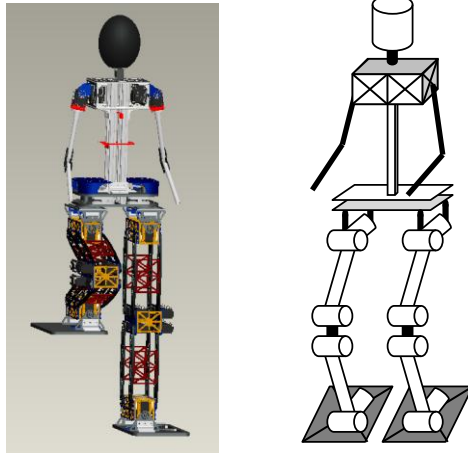
## **2 Mechanical Design**

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 2013. The HuroEvolution is designed as a 9 degree-of-freedom robot, where 8 degrees of freedom is desired for the lower limb, and 1 degree of freedom is for the pan motion of the active vision sensor on the neck. 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.

Height (cm)		149	
Weight (kg)		15	
DOF	Leg	8	
	Head	1	
Actuator		Robotis EX106+	
		Robotis RX28	
Sensor		CCD Camera (DFM 22BUC03-ML)	
		Gyro Sensor	RM-G145
		Acceleration Meter	
Control System	Main Controller	Pico 820 Single Board Computer	
	Motion Controller	ATmega1281	

### 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;  $\rho$  is the time percentage of the period time when the foot reaches to the highest position;  $T_s$  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  $\theta_{pitch}$  is generated from the locomotion trajectory;  $\omega_{pitch}$  and  $\omega_{roll}$  are the measured angular velocity.

$$x_s(t) = \frac{Length}{2\pi} [2\pi \frac{t}{T_s} - \sin(2\pi \frac{t}{T_s})], \quad 0 \leq t \leq T_s \quad (1)$$

$$y_s(t) = \frac{Shift}{2\pi} [2\pi \frac{t}{T_s} - \sin(2\pi \frac{t}{T_s})], \quad 0 \leq t \leq T_s \quad (2)$$

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

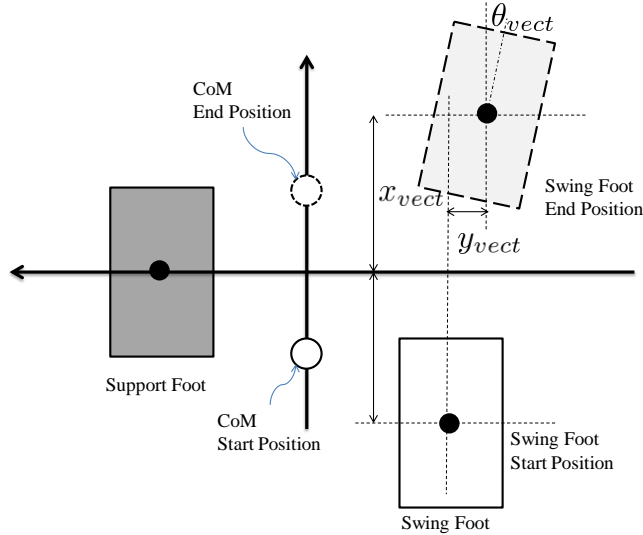


Fig. 2. The graphic symbols of the locomotion parameter.

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

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

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.

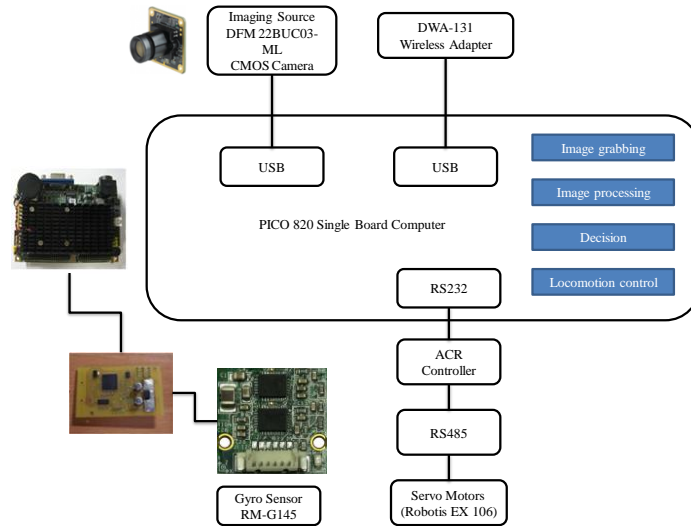


Fig. 3. Control architecture of HuroEvolution robot.

## 4 Conclusion

This paper presents an adult size humanoid participating in the RoboCup 2012. The parallel mechanism structure is designed to reduce the back lash effect and light the weight. The omni-walking locomotion is also proposed in this paper. In order to achieve the robust walking ability, a PD controller is implemented. The distortion justifications and geometric parameter identifications of the CMOS camera were done before applying the visual localization approaches. In the end, several challenges are

discussed. The result as shown by using continuous video frames captured from competition. In the future, the upper body is constructed to achieve multiple function service robots.

## 5 References

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