Team Description Paper for Team TH-MOS

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Abstract. This paper describes the design aspects of mechanical and electrical parts as well as the software components of a humanoid robot participating in the Kid-Size competition, Humanoid League of RoboCup. Research fields related to the built platform are concepts of mechanical design, gait generation, dynamic image processing, behavior control, and communication. An omnidirectional gait generating strategy is proposed and a fast vision processing method is implemented on the robot.

Keywords. Humanoid, soccer, omnidirectional walking, behavior

1 Introduction

RoboCup Humanoid League supplies a designated task as the standard for diversified biped platforms. Upon this, mechanical and electrical design evolves every year to cope with remaining problems. Humanoid teams focus on both stability of locomotion and artificial intelligence. These research fields extend as several parts as online motion planning with real-time adaptation and stability, precise and robust object identification with vision system, decision making ability in a rapid changing environment, and inter-robot communication for cooperating [1].

The team TH-MOS from Tsinghua University joined the league since 2006, and had developed several kid-sized humanoids since then. The research focused mainly on online gait generation for omnidirection walking, cognition-motion compliance, and cooperation based on multi robots. The newly designed MOS-Lite and MOS-Strong has reached the tasks to some extent. A short view of the hardware and software concepts is as follows.

2 Mechanical Designs and Power Supply

The skeleton of both MOS-Lite and MOS-Strong is mainly constructed with aluminum alloy to reduce weight and keep rigidity. And actuators are all servos diversified in Torque and Speed. For robot flexibility, 6 DOF is allocated in each leg, 2 among which constitute ankle joint(roll, pitch), 1 in knee joint(pitch) and 3 in hip joint(roll, pitch, yaw) intersecting at one point, for such configuration in hip simplifies forward and inverse kinematics[2]. One joint is in waist (yaw) for upper body turning when kicking ball or getting-up actions; there are 3 DOF in each arm, sufficient for getting up, and two in neck for camera navigation. All these DOF allow flexible movement and the working ranges are enough for any common and special actions, and thus fulfill the locomotion request. Fig. 1 shows the outline of MOS-Strong and MOS-Lite. Both robots have a similar kinematical design, but differ in size, weight, mass distribution and servo motor used.

Besides DOF configuration, parameters of different parts like leg length and ankle height vary a lot and play an essential role in locomotion. We derived these disciplines from gait generating algorithm, which is simulated upon the method described in 4.1.

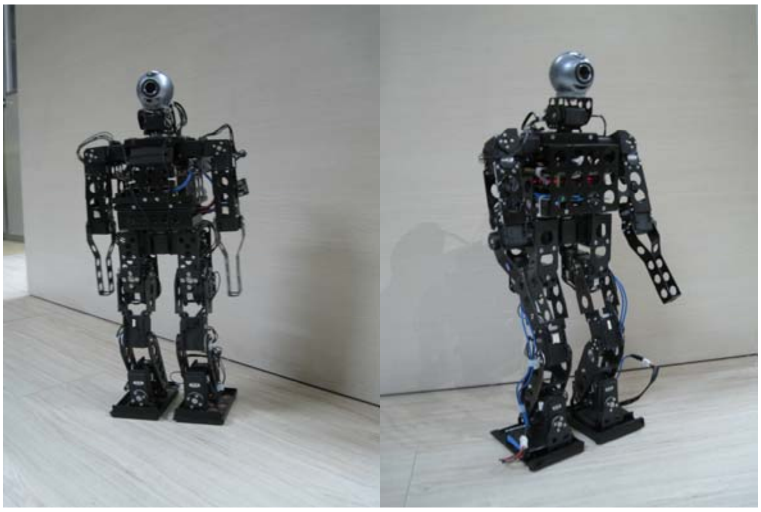

Fig. 1. MOS-Strong and MOS-Lite Appearance

Device of power supply is always neglected in RoboCup humanoid design, while it stands an important role in navigating extension. Batteries and voltage converting module mounted on the robot have to supply sufficient current for biped robot walking, as well as stable voltage for control system and heterogeneous servos, and all in all, keep in light weight. Some teams simplified the voltage for different servos by narrowing down to only one level [3], which may lead to the shortening life or discount of torque for the specific servos.

In MOS-Strong and MOS-Lite, Li-ion batteries and a converting module are mounted, which could supply 3 kinds of voltage: 5V for controllers, low level which is converted through the main battery for upper body servos, and another high level directly from battery for lower body drivers. High-efficiency DC-DC converter is utilized and the voltage could be adjusted according to different selections between MOS-Strong type and MOS-Lite type, and thus, both of the robot share the same voltage converting module.

3 Control System and Sensors

We devise the robots in concept of distributed system with 2 controllers, named locomotion layer and decision-making layer. MOS-Strong and MOS-Lite are equipped with an ARM-based motion controller, clocked at 100MHz as its locomotion layer. It is interfaced with RS485 converter and semi duplex TTL to control all the servos. A/D converters read data series from dual-axis accelerator and gyros. SRAM and flash expansion facilitates this layer to store as many as gait origination. The high speed fix point core allows density of calculation to execute online gait generation and modulation.

The decision-making layer is an X86 industry embedded computer with an operating system of Linux, which streams frames from USB webcam, executes behavior process, and responds to commands outside the play filed. Two layers communicate with each other through RS232 at a baud rate of 115200. Details about the robot system are listed in Table 1.

Table 1. Technical Data of Robots

Type	MOS-Lite		MOS-Strong	
Servos	RX28	AX12	RX64	RX28

Torque[Kg.cm]	28.3	16.5	64.4	28.3
Speed[sec/60°]	0.167	0.196	0.188	0.167
Sensors:				
Camera	Logitech QuickCam 5000		Logitech QuickCam 5000	
Resolution	640×480		640×480	
Color space	YUV		YUV	
Frame rate [fps]	30		30	
Accelerometer	2 axes		2 axes	
Gyro	2 axes		2 axes	
Degree of freedom	21		21	
Height [mm]:	576		583	
Weight [g]:	3025		5341	
Walking Speed[m/s]	0.24		0.20	

4 Algorithms

Robot for RoboCup competition is an autonomous agent; functions can conclude as gait planning and modulation, vision processing, decision-making or behavior, communication and information share.

4.1 Online Generated Omnidirectional Gait

The gait of most bipedal robots is controlled by precomputed trajectories, however, in the robot soccer game, a dynamic environment forces the robot to adapt their walking direction, speed and rotation to the changes [4]. A robot has to approach any point and module himself toward a preferred direction while avoid any collapse with obstacles on path. Based on predefined walking styles, complex path planning algorithm is needed. The generated series of gait can be eliminated when surrounding varies to some extent.

Our goal is capsulate the biped robot into an omnidirectional moving platform in the view of the mounted camera on head, and making gait parameterized with 3 parameters: offset in forward and sidle direction and another rotation direction around z axis.

Several walking strategies have been developed, most of which are based on the Three-Dimensional Linear Inverted Pendulum [5]. Firstly, foot trajectory is directly deduced from the foot planner from the gait command. Second, the center of pressure trajectory is defined based on ZMP discipline. COM trajectory is simply related to that of COP assuming the robot as a three-dimensional linear inverted pendulum [6][7][8]. Third, inverse kinematics generates joint trajectories based on the former foot and COM trajectories. An analysis resolution of inverse kinematics can be derived from the specific hip configuration of MOS-Strong and MOS-Lite, which ensured the 3 joints intersected on a single point. [2] had issued the details of this method.

In our research, multiple formulas describing the trajectories are sampled, normalized, and saved in motion control board, and thus both of trajectory type and gain can be adjusted offline, and leaves joint trajectories generated online. An accelerating and decelerating algorithm is also developed to cope with a sudden change of walking speed command from behavior.

4.2 Vision Processing

The multicolor image segmentation is the most important part in vision processing. To be robust enough to deal with the complex environment of robotic soccer, the vision processing does not only make use of traditional algorithms to deal with the multicolor image, but also uses a very fast segmentation algorithm.

In MOS-Strong and MOS-Lite, In order to balance the processing speed and recognition precision, we introduce a changing scan step over pixels rather than a progressive scan step from pixel to pixel. The step length is related to distance from the scan line in Cartesian coordinates reflected to image based on pin-hole model. The scan line generation can be illustrated by Fig. 2.

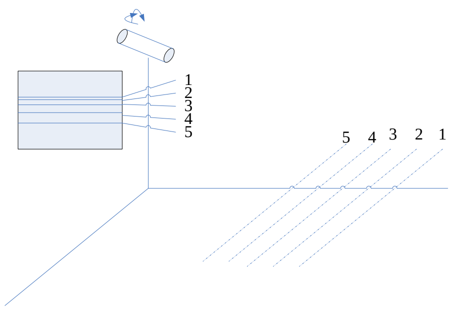

Fig. 2. Scan Step Variation to Cartesian Distance

Clustering process, the most time consuming part has been made efficient by diversified step from the prior knowledge of the target object, such as the possible diameter of football, the extension of goal and flag bar. Filtering is mainly executed based on this knowledge rather than an aim-less smoothing.

4.3 Behavior

Behavior module is constructed with finite state machine, considering the endless changing environment while playing football. Basic states include start state, searching football, searching shooting target, walking toward football, shooting at target, and emergency when falling. Vision information and robot posture feed back join to supply resources for state adjustment, making the robot perform according to various circumstances. Fig. 3 shows the example of state flow of penalty kick strategy.

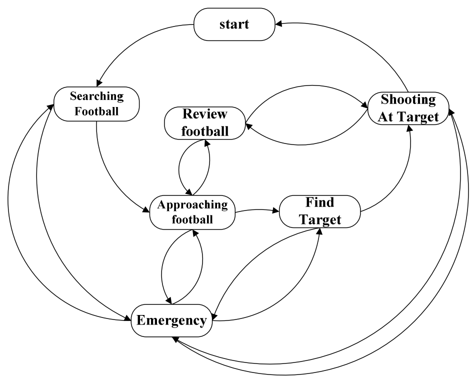

Fig. 3. State Flow of penalty kick strategy

4.4 Communication

Communication includes information share between different robots and instruction and feed back among robots and human machine interface. It depends on WLAN in hardware; a network platform aimed at gap-less information, especially synthesis of environment fuzzy description is on research based on MOS, for efficient information share will make cooperation possible within a team. Robots in humanoid league do not depend on a central controller off board. On the contrary, they make decisions themselves. Shared information, including decision path, description of playfield and ball, perform as other sensors of a robot. Cooperation in such system needs further development.

5 Conclusions

In this paper, improved humanoid robots, MOS-Strong and MOS-Lite are investigated in specification. We also proposed an omnidirectional gait generation method; speed and precision balanced object reorganization algorithm is developed and put to use in MOS robots. Communication and cooperation is realized by means of WLAN. Multi-robots system cooperation with independent decision-making agent will be further developed based on the platform.

Commitment

Team TH-MOS will definitely participate in the RoboCup 2012 Humanoid League competition and make a team member with sufficient knowledge of the rules available as referee during the competition, if we are selected and qualified.

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