ENDEAVOR Team Description Paper 2010

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Abstract. This paper mainly introduces the middle-size robot soccer team "ENDEAVOR" for the purpose of qualification to RoboCup MSL 2010. This team has been built and developed by the authors from scratch since 2006. The robot's hardware and software have been improved through three-generation prototype. The general architecture of the robots is firstly described in this paper. The robot's hardware and software including omni-directional vision, self-localization, the ball active handling device, role auto-switch are introduced in this paper. The current research activities focus on system improvement, situation recognition, path planning, parallel processing and the coordination between robot teammates.

1 Introduction

The ENDEAVOR team is a new RoboCup middle-size league soccer team built by Robot Innovation Group at Department of Electronic Engineering, Wenzhou Vocational & Technical College in 2006. Since then we have developed three generation mobile robot prototypes. Figure 1 and Figure 2 show the first and second generation robot prototype, which were individually developed in 2007 and 2008. The first generation robot was driven in a differential way, while the second and three generation one were type of all-directional motion. During the last two years, we attended different robot soccer competitions of China. After two years continuous improvement, this team made great progress. Currently, this team involves four college staff members, three joint researchers and more twenty college students in all.


Fig. 1


Fig. 2


Fig. 3

This ENDEAVOR team took part in the China Open 2009 for the first time in the Middle-Size League, which was held at Dec. 19-24, in Shanghai, China, and unexpectedly won the championship of soccer game and 3rd prize of technical challenge game. The success comes from not only hardware reliability and efficient algorithms of the robots, but our continuous effort for last few years.

This team is expected to compete for the first time in RoboCup MSL 2010 in Singapore. This paper is part of qualification materials for RoboCup 2010.

Robot Innovation Group is a multi-disciplinary group focused on robotics teaching and researching. Besides, the activity of this group has covered the participation in several robot and technical competitions at national and local levels, for instance, Grandar Cup Intelligent Robot Competition of China (national), Mitsubishi Motor Automation Cup Science & Technology Innovation Contest of University Students (national), RoboCup China Open (national) and some local robot contests. The authors highly expect the ENDEAVOR robot soccer team to attend the international RoboCup 2010, which provides a great chance to promote robot research for us.

Since this team built and developed several robot prototypes, the authors expect to contribute to the state of the art in the following fields: robot system architecture, omni-directional vision, all-directional motion control, localization, path planning and multi-robot coordination. During the development and improvement of the robotic systems, many different technologies have been integrated.

This paper describes the current development stage of the team and organized as follows: Section 2 introduces the software architecture of the robots. Section 3 and Section 4 describe the omni-directional vision system and robot self-localization. The active ball handling is introduced in Section 5. Section 6 introduces ball velocity and position estimation. Role auto-switch and path planning are described in Section 7 and Section 8, Section 9 provides coordination between teammates. Section 10 gives the conclusions of this paper.

2 System description of the robots

2.1 Mechanical structure, sensors and actuators

The present ENDEAVOR team robot players are designed and developed based on continuous improvement for the last few years. The physical configuration and size of the robots totally accord with RoboCup MSL rules. The team includes 5 robot players, one of which is goalie. The current ENDEAVOR team robots are shown as figure 4.

Fig. 4 ENDEAVOR team robots

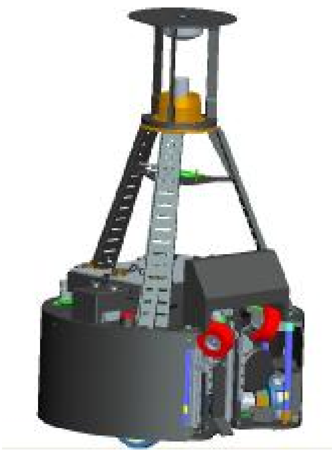

Figure 5 3D design of the player

The basic frame of the robot is a cylinder envelope, as in Fig.5. The mechanical structure of the robot can be mainly separated into four layers. The lowest layer is motion device, shown in figure 6, including the motors and all-directional wheels. Figure 7 shows the second layer, containing pneumatic ball-kicking devices, ball-dribbling device, motor controller/drivers and battery box. A laptop computer is laid on a aluminium plate, which refers to the third layer, shown in figure 8. The top layer consists of compass sensor and all-directional vision unit, as in Fig. 9.

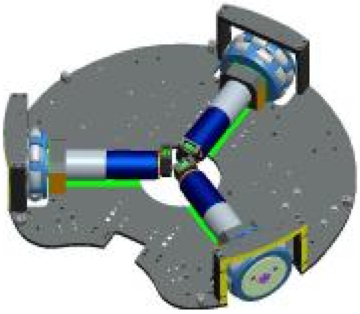

Figure 6 motion device

Fig. 7 pneumatic ball-kicking devices, ball-dribbling device

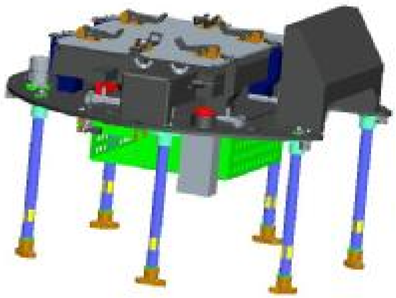

Fig. 8 Laptop mechanism

Fig. 9 Vision and compass mechanism

The robot is capable of performing all-directional motion based on three omni-directional roller wheels. Each wheel is actuated by a 150W/24V DC servo motor. Each motor rotation velocity is feedbacked by an optical encoder. A DSP-based microcontroller is developed to control the servo motors. The detailed control architecture will be introduced in the following context.

Ball kicking device of the robot is usually designed in a pneumatic or electromechanical way. The electromechanical way is used by many RoboCup MSL teams. However, the pneumatic kicker is light and physically simple. So the pneumatic way is still accepted in the design process of the robot. An aluminum bottle as air container is used to supply pressure to air cylinder. Unfortunately, pneumatic kicker has a disadvantage of pressure declining after it works for several times. So the air pressure is detected by a pressure transmitter to adaptively control the conducting time of the electromagnetic valve. To kick ball the same distance, the conducting time lasts long if the air pressure is low, vice versa.

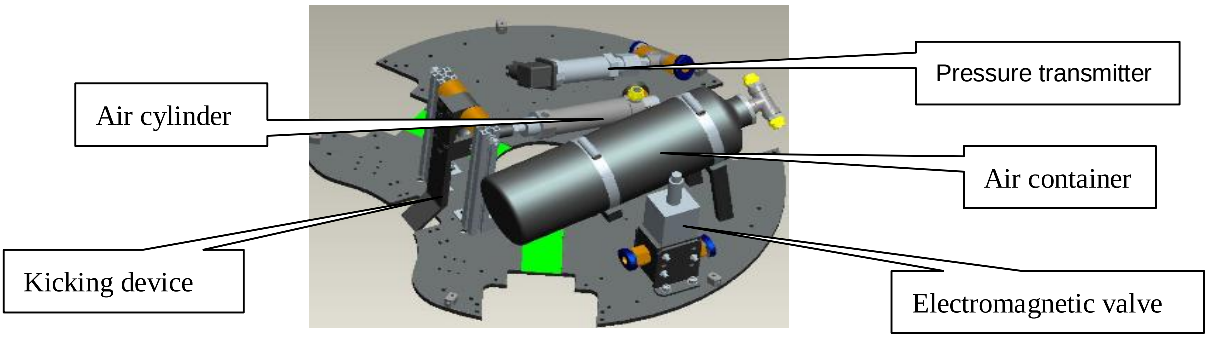

Fig. 10 The ball-kicking device

There are two types of way to develop dribbling device, passive or active way. The past robot soccer competition proves that active dribbling mechanism is quite helpful for the player to compete. So we have spent much time to develop the active dribbling device for the current robot player. Fig. 11 shows the three-dimentional modeling. Fig. 12 shows the premier design prototype, while Fig. 13 shows the revised version of our dribbling mechanism. Two ball dribbling DC motor with angled gear boxes are installed on straight lead trail. The ball dribbling is performed by individually control the rotation velocity of the two DC motor in a close-loop way.

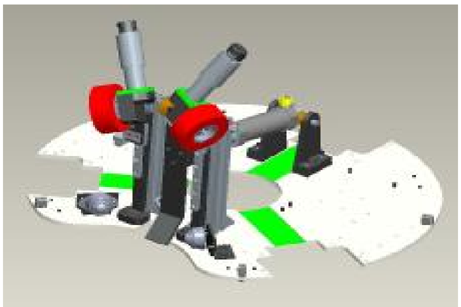

Fig. 11 3D modeling of the active ball dribbling mechanism.

Fig. 12 the premier design prototype

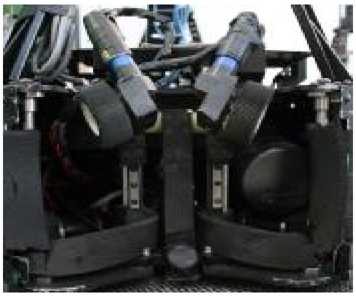

Fig. 13 the revised version of our dribbling mechanism

2.2 Control architecture of the robots

The control hardware mainly includes two parts: main control computer and bottom motion control system. A laptop computer is used as the main controller, while the bottom motion control system utilizes a DSP-based control board, shown as in Fig. 14. The bottom DSP-based control board is in charge of actuation motor control, ball dribbling motor control, ball kicking control, sensor data collecting, synthesis of wheel velocity and acceleration. DSP-based control board is connected to laptop through USB port. In the experiment, we found that this kind of control architecture can greatly reduce the computation amount of main control program and the communication times between the laptop and the DSP-based control board. The control board uses the 150Mhz DSP processor. Its peripheral connections include three 150W DC motors used for driving the robot, two 10W DC motors used for dribbling ball, one pressure transmitter used for measuring the air pressure, two PSD and one digital compass. The communication rate between laptop and DSP can be up to 1Mbps through using single-chip USB to UART Bridge.

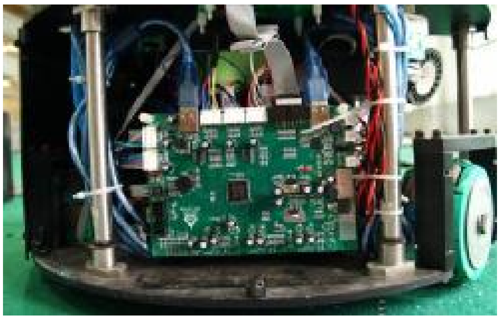

Fig. 14 Bottom control board

Camera and wireless LAN are individually connected to laptop through 1394b firewire and USB port. In the China Open 2009, the camera's sampling frame rate was set to 30fps. However, the actual calculating time consumed at experiments was about 8 to 10ms, so we expect to improve camera's sampling frequency to a higher value. The whole system flow chart is shown as follows.

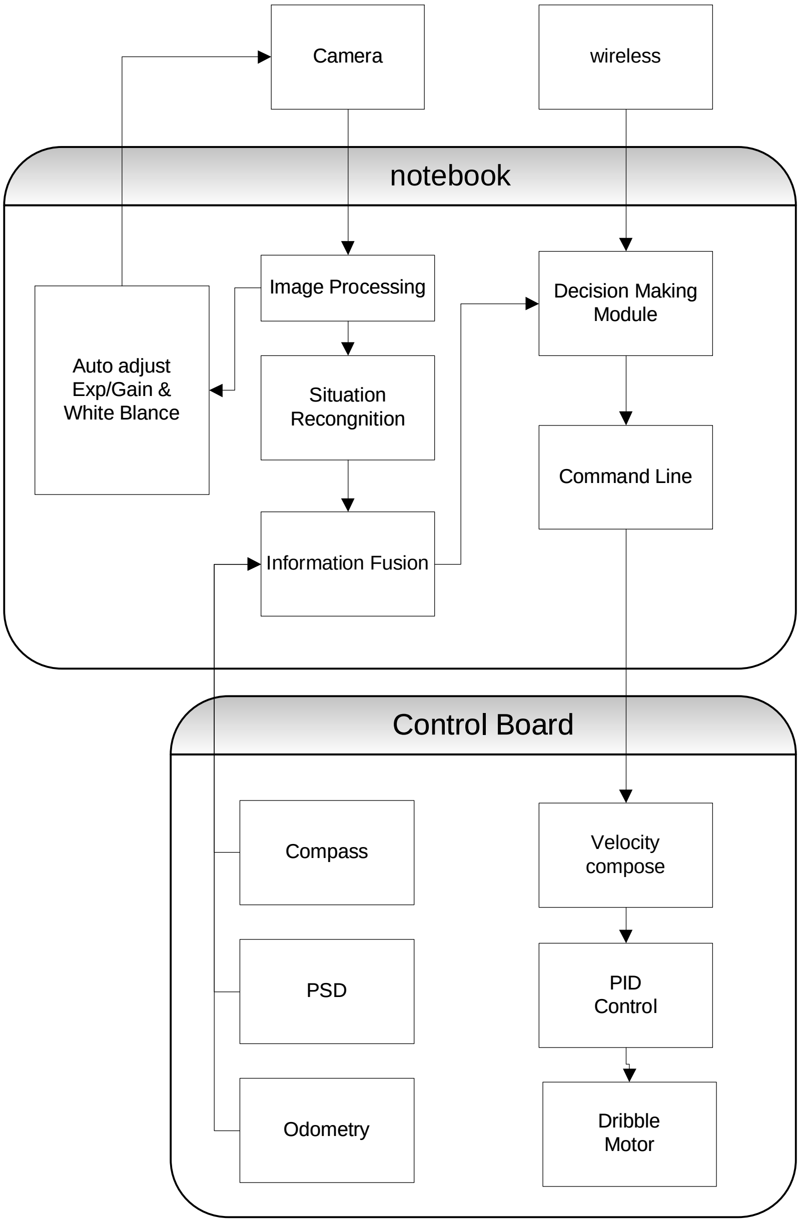

Fig. 15 The control architecture

3 Omni-directional Vision System

3.1 Vision system description

One of key parts in the design process of the robot is vision sub-system, which plays an important role for robot performance. The omni-directional vision sub-system consists of a 1394b firewire camera and a hyperbolic mirror. The hyperbolic mirror placed above the camera reflects the 360 degrees of the area around the robot.

Fig. 16 Vision system of the first generation

Fig. 17 Vision system of the second generation

Two different vision sub-systems had been introduced during designing three-generation robot prototype. The first one used a glass-column as a supporting pole for hyperbolic mirror, as shown in Fig. 16. This vision system did not perform well because the manufacturing accuracy of glass-column was hard to be guaranteed. Moreover, the glass-column had serious internal reflection, which brought light spot in the image, as Fig. 18 shows. The light spot had bad influence to image processing and object recognition. So a new vision mechanism has been designed. In the second-generation vision system, hyperbolic mirror is supported through three equally-disposed metal poles, as shown in Fig. 17. Fig. 19 shows the image captured by the new vision system.

Fig. 18 Image captured by the first-generation one

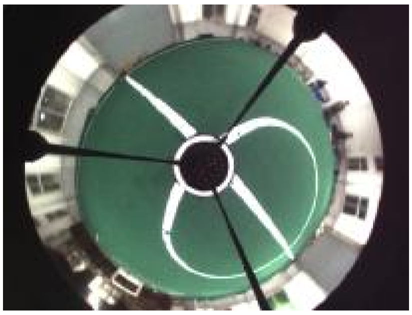

Fig. 19 Image captured by the second-generation one

Hyperbolic mirror is designed and manufactured, as Fig. 20 and Fig. 21 show. The mirror material is aviation aluminum alloy.

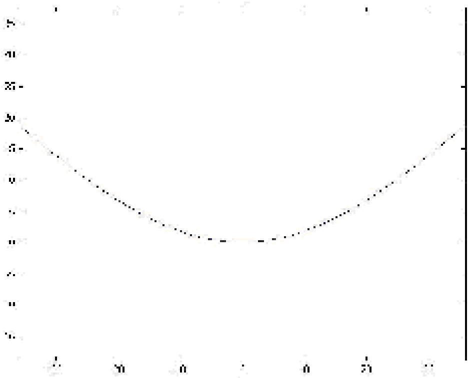

Fig. 20 Hyperbolic mirror profile

Fig. 21 The manufactured mirror

3.2 Camera parameters self-adjustment

Light exposure is one of key parameters for camera to obtain high-quality image. Digital industrial camera usually can automatically adjust exposure parameter. But automatic exposure of camera maybe results in excessive exposure problem. So we calculate the mean sample value (MSV) from the histogram to determine the balance of the tonal distribution in the image. The calculated exposure parameter is set to camera through application program interface (API) to obtain better image.

Fig. 21 Adhesive tape installation.

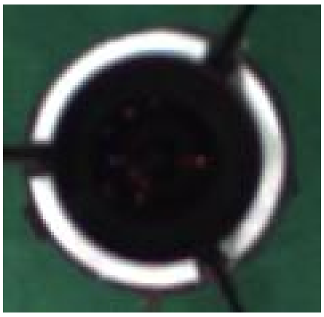

Fig. 22 Original image of adhesive tape.

Since white field line is utilized in robot localization algorithm, robot localization performance is seriously affected by recognition accuracy of field line. But recognition of field line can be badly affected by environment light. To obtain better image of field white line, we stick white adhesive tape on camera's installation base as a reference to adjust white balance of camera, as shown in Fig. 21. Fig. 22 shows original image of the white adhesive tape. The whole process of camera parameters self-adjust is shown as Fig. 23.

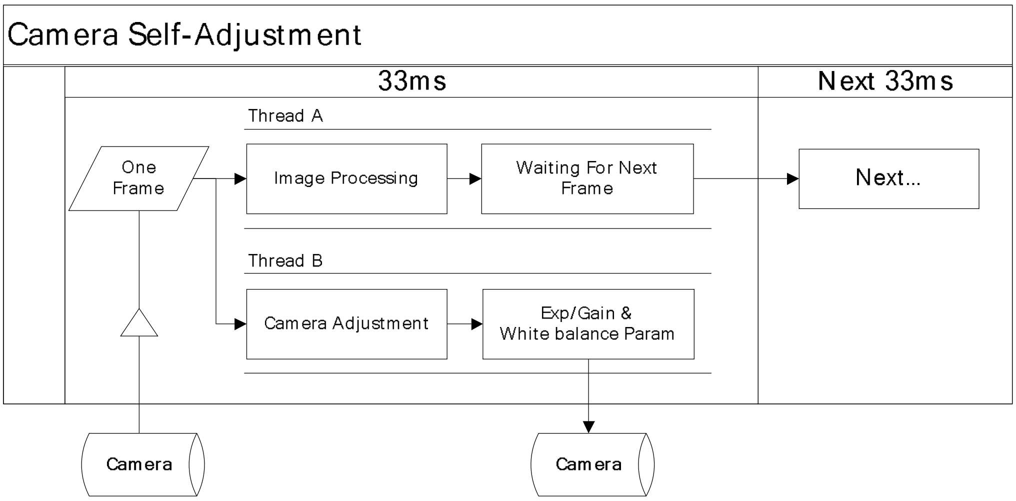

Fig. 23 Camera self-adjustment

3.3 Parallel processing

To reduce computation amount, original image is processed by a radial scan way, shown in Fig. 24. Information of each scan line takes turns to be captured for serial computation. During physical experiments, we found that one CPU of dual-core laptop operates to full load, while the other stays idle. So we try to introduce parallel computation to image processing. Table 1 shows pseudo-codes of serial/parallel computation comparison.

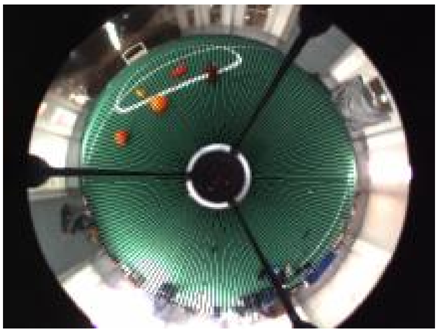

Fig. 24 Radial scan line for original image

Table I Pseudo-codes of serial/parallel computation comparison

Serial Computing	Parallel Computing	
For each scan line in 360 degree Detect Landmark. End for	CPU1: For 1 to 180 Detect Landmark End for	CPU2: For 181 to 360 Detect Landmark End for

Table II

	Serial Computing	Parallel Computing
Cost-time (average 10000 times)	3.2 ms	1.8 ms
CPU1 Efficiency	90%	86%
CPU2 Efficiency	20%	80%

Physical experiments had been implemented to compare cost time of serial and parallel computation. The robot's main processor is a ThinkPad laptop with Intel Core2 Duo 2.40Ghz, 2G memories under Windows XP SP3 operating system. All code is implemented in C++ language.

4 Self-Localization

In the MSL, the environment is completely known, so we used the approach described in [1], with some adaptations. According to our experimental results, beginning search direction plays an important role to localization performance. Robot localization is determined by (x, y, θ). For x and y components, error vectors are chosen for search vector directions, as Fig. 25 shows.

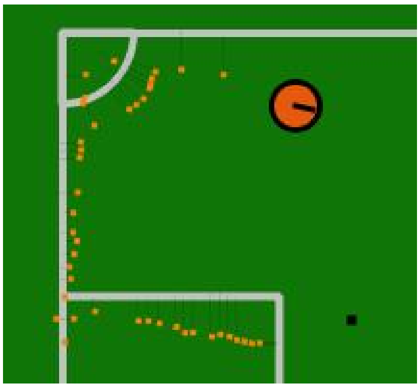

Fig. 25

Fig. 26

For computing search direction of θ component, we calculate the total average “force” on each landmark with Error_Map, starting from the current robot position, shown in Fig. 27. Then we add all forces acting on the robot center, and select the nearest landmark which has a greater contribution to total “force” estimation.

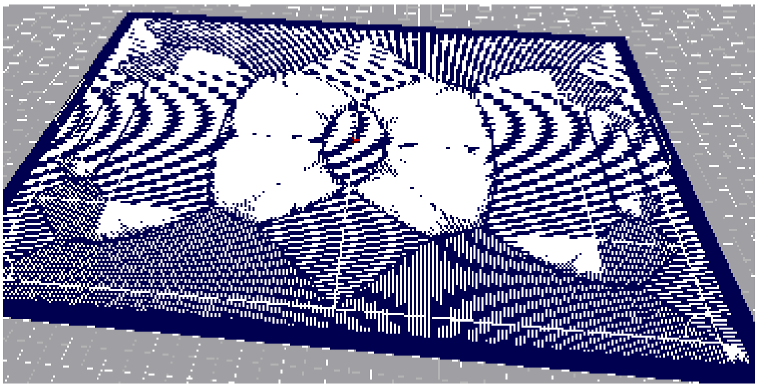

Fig. 27 Error map

Revised localization algorithm greatly reduces match error times and iteration times. One of key issues affecting robot localization is dithering image caused by robot collision during competition. To improve localization performance, an extended Kalman filter was utilized to fuse visual information, odometry information and digital compass data. The EKF process is shown as in Fig. 28.

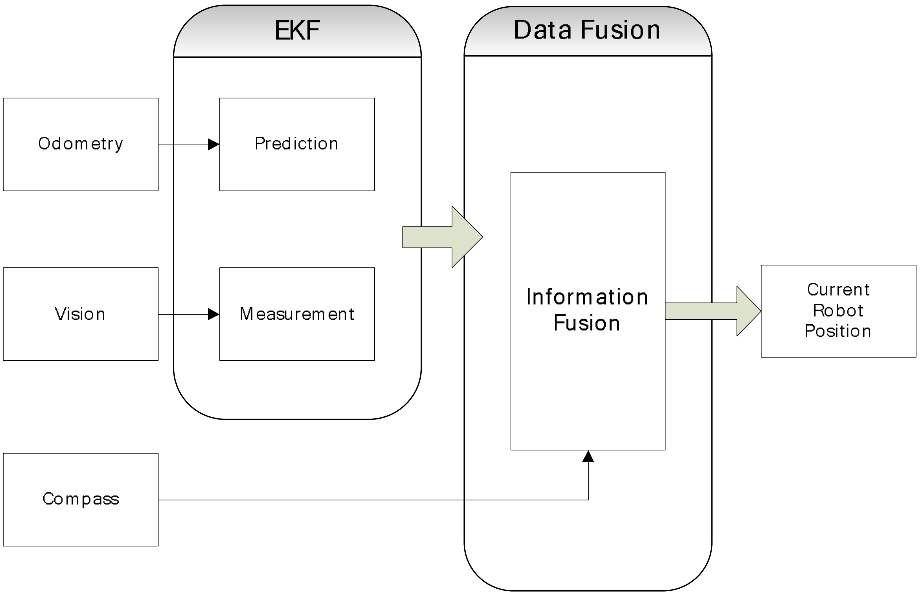

Fig. 28 The EKF process of sensor fusion

Computation speed and reliability of the revised localization algorithm was obviously improved. According to physically experimental results, average cost-time of the revised localization algorithm is less than 2ms. During RoboCup China Open 2009 competition, the players did not lose localization even once.

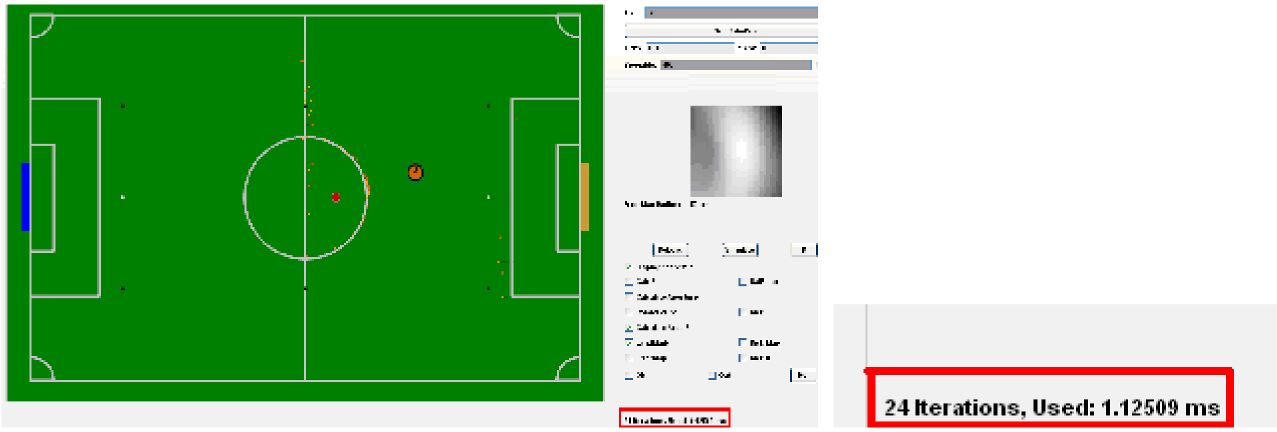

Fig. 29 Cost time of the revised localization algorithm

5 Ball Velocity and Position Estimation

To gain reliable ball velocity and position estimation, we develop a novel method to estimate the velocity of the ball, which is based on Kalman filter and PROSAC algorithm. Firstly we restore pre-several cycles (6<N<12, N means cycle times) of the ball position and use Kalman filter to smooth the positions. Then we randomly choose several possible velocities between every two cycles to calculate the most-likely velocity and position. Rather than RANSAC method, which treats all correspondences equally, we use PROSAC algorithm to estimate the velocity and position. The PROSAC algorithm terminates if the number of inliers within the set satisfies the following conditions: non-randomness and maximality. Fig. 30 shows the ball velocity and position estimation results.

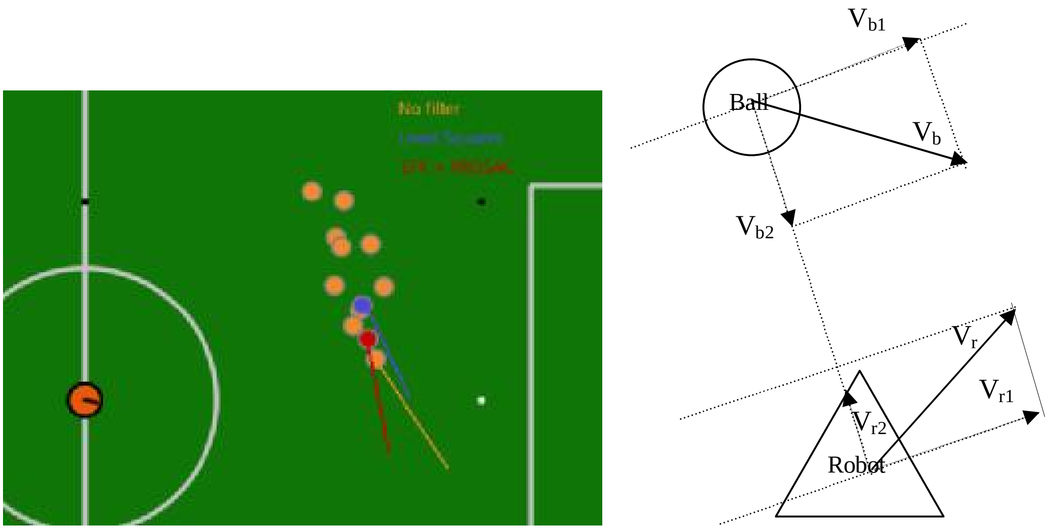

Fig. 30

V_b is estimated ball velocity, V_r is computed velocity of robot according to ball velocity.

$$V_{r1} = V_{b1} \quad (1)$$

$$V_{r2} = V_{b2} + C \text{ (C is a constant)} \quad (2)$$

6 Role Auto-Switch

Each ENDEAVOR robot player is an independent agent and has dynamic roles. Each robot player decides its own role with current strategy and teammate information. six roles are defined for the ENDEAVOR robots: Striker, Assistant_Striker, Left_Defender, Right_Defender, Middle_Defender and Goalie. Every player has a dynamic role, except goalie. Another role RoleDebug is defined for debugging.

At the beginning of the game, each robot is set to be assigned role. When the game starts, the robot will invoke decision making module to change its role according to current strategy defined before the match, CCD information and information from its teammates. The whole process is as follows.

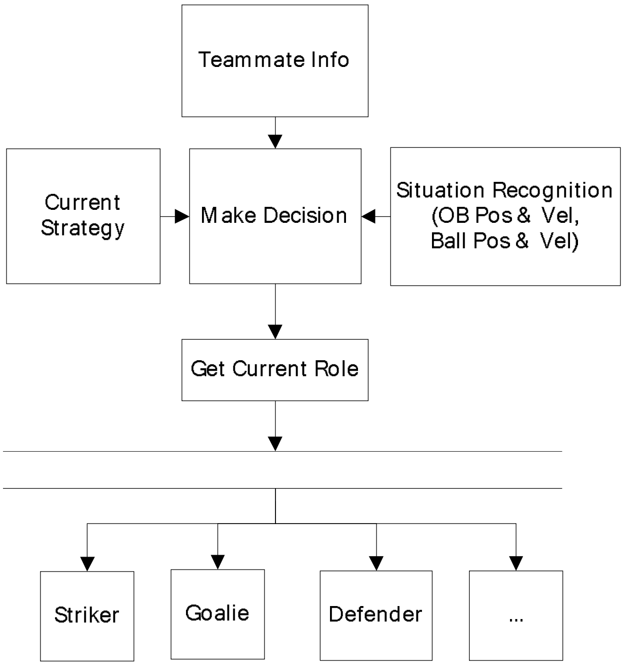

Fig. 31 Role auto-switch process

7 Conclusions

This paper describes the current development stage and robot system of the ENDEAVOR team for the purpose of qualification to RoboCup MSL 2010. This team has been built and developed by the authors from scratch since 2006. The robot's hardware and software have been improved through three-generation prototype. The general architecture of the robots including omni-directional vision, self-localization, the ball active handling device, role auto-switch are briefly introduced in this paper. In the future, we will focus on several topics such as system improvement, situation recognition, path planning, parallel processing and the coordination between robot teammates. Other information about this team can be visited on our group website.

The ENDEAVOR team is new team to RoboCup MSL, but highly hopes to participate in the international RoboCup MSL in Singapore. In the last, we would like to thank all of members of the robot innovation group.

We are willing to joint RoboCup MSL 2010 as a united team.

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