NuBot Team Description Paper 2007

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Abstract. The paper mainly describes the implementation of our middle-size league robot team "NuBot" for RoboCup 2007. The description consists of both the hardware design of the robot vehicle and the fundamental control & AI software running on its onboard computer. The current research focuses on robust robot vision, perfect world model building and multi-robot cooperation.

1 Introduction

RoboCup (Robot World Cup Soccer Games and Conferences) is an international research and education initiative. It aims to foster artificial intelligence and robotics research by providing a standard platform where a wide range of technologies can be examined and integrated. The middle-size league competition of RoboCup is a standard real-world test bed for autonomous multi-robot control because all robots are completely autonomous. Our middle-size league team "NuBot", founded in 2004, participated in RoboCup 2006 for the first time in Bremen, Germany. We also participated in 1st RoboCup China Open in 2006 and won the first place. Our research focuses consist of multi-agent cooperation, multi-robot control architecture, path planning, robot vision, image processing, omni-directional movement control and multi-sensor fusion.

In the following part, we will first describe the implementation of our current robot team, involving the applied hardware, computer vision system, and fundamental control & AI software system, and then introduce our current research focuses.

2 Hardware

Every fully autonomous robot of "NuBot" is equipped with an omni-directional vision system, a normal camera as front vision, and an electromagnetic kicking device. The robot is controlled by a notebook PC (Acer TM3000), which is demonstrated in figure 1. The chassis of the robot is designed as a frame construction where there is the electrocircuit board, batteries, kicking device, motor controller and notebook PC. The omni-directional vision system and the normal camera are on the top of the framework.

Fig. 1. Our current robot. The robot is a 4-wheeled omni-directional mobile robot with an omni-directional vision system, a normal camera and a kicking device, and is controlled by a notebook PC.

The omni-directional movement system consists of omni-directional wheels, DC motors, a drive shafting system and a controller. The four omni-directional wheels are the key component of the robot, each wheel radially equipped with dozens of small wheels, as shown in figure 1. The four-wheel drive robot can move at any direction and at any moment. Although three such wheels are sufficient for the robot to move omni-directionally, a fourth wheel can provide redundancy in motion and control [1]. These wheels are driven by Maxon DC motors, in which there are encoders for the control of the speed and dead reckoning. The electrocircuit board is composed of DSP (TMS320F2812) and CPLD chip. And peripheral circuit is the controller of these DC motors and kicking device.

The omni-directional vision system consists of a panoramic mirror, a firewire color digital camera (Prosilica EC650C) and a regulation device. The panoramic mirror, designed by ourselves, is made up of an isometric horizontal mirror and an isometric vertical mirror, as shown in figure 2(a). The mirror can make the resolution of the images of the objects near the robot on the field constant and make the distortion of the images of the objects far from the robot small in vertical direction, as demonstrated in figure 2(b), which is a typical panoramic image we captured in Bremen when participating in RoboCup 2006. The regulation device can adjust the height of the omni-directional vision system and the distance between the panoramic mirror and the camera.

In addition to the panoramic vision system, each robot is equipped with a normal inexpensive USB camera as front vision, so that the field of view can be up to 140° by using the wide-angle lens. This USB camera can help to improve the accuracy of the ball and obstacles recognition, which satisfies the demand for precise robot control, such as dribbling, obstacle avoiding and shooting.

The notebook PC is responsible for the control of the robot. It captures images of the field from the digital camera through the firewire interface, and processes these images for self localization, the ball and other robots localization. Then the PC makes decisions about the motion of the robot and sends commands to the motor control board via a serial port. The robot can communicate with its teammates via a wireless network based on IEEE 802.11b.

(a) (b)

Fig. 2. The panoramic mirror and the typical panoramic image captured in Bremen, 2006

3 Software

The robot control software is based on a behavior-based hierarchical architecture for mobile robots [2]. The basic idea is to make the system more modular than existing ones. The general structure of the control software is shown in figure 3. This hierarchical architecture is divided into a sensor hierarchy and a behaviors hierarchy. The sensor hierarchy is composed of six modules, five of which process the information from the omni-directional vision system, the normal camera, the odometer, the user interface and also communication with other robots. The other one predicts locations of the objects (robots and ball) in the field by using the Kalman Filter. All modules maintain a world model, where all necessary world states are stored. The behaviors hierarchy is separated into five layers: the motor control layer, the basic behaviors layer, the actions planning layer, the role allocation layer, and the formation negotiation layer. All behaviors are executed in parallel. Under the control of such architecture, NuBot can respond to changes in a match as quickly as possible.

The software is programmed by C++, based on multithreading programming technology [3]. The framework of the software consists of three threads: one mainthread for robot control, decision and communication, one subthread for the image processing of panoramic vision and self-localization, and the other subthread for the image processing of normal camera [4]. The mainthread determines whether to suspend or resume the two subthreads according to its need, so the omni-directional vision and normal camera can work together at maximum processing speed.

In the image processing algorithm of omni-directional vision, the image is firstly segmented by color lookup table calibrated off-line, and then the markers, such as white line points, goal, etc., are detected by feature detection, and finally the targets are recognized, such as ball, goal, the other robots and so on. Based on these features and odometry, the robot's self-localization is achieved by using Monte Carlo localization method. The outputs of the image processing involve the robot's position and orientation, the positions of ball, goal, and the other robots.

In the image processing of normal camera, the robots only need to segment the image and then recognize the ball and obstacles. Artificial neural network is adopted to calibrate the bad imaging distortion caused by using the wide-angle lens in this camera.

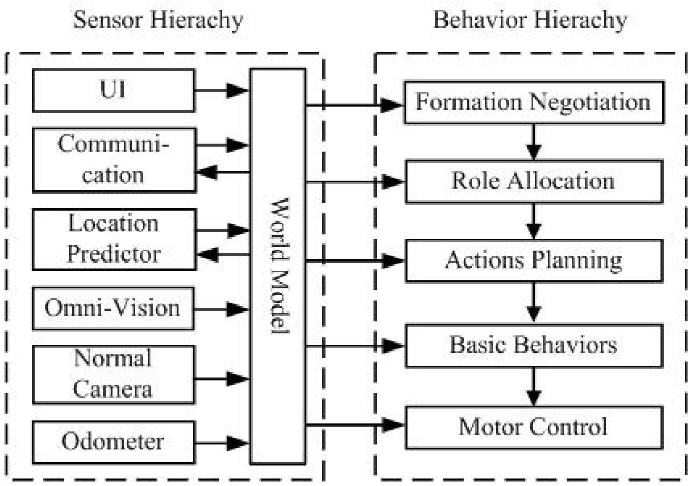

Fig. 3. Overview of the control architecture applied to NuBot

For the behavior hierarchy, all the teammates will corporately decide the current formation type and allocate predefined roles among themselves on the basis of the negotiated formation [5].

Our robot team formations are defined into three types: attack formation, defend formation and intercept formation. All the robots should negotiate in a distributed way to choose formations based upon the situation that which side is controlling the ball and that which region the ball is in.

Since five robots are employed in the competition, five roles are defined as goalie, active, defender, left and right assistant. After the appropriate formation is selected, the team strategy is just to distribute these roles among the robots in a distributed and dynamic way. As in the real competition, one or more robots may fail because of unexpected collisions, we define the above roles in an order of priority, that is, the goalie is the most important role and the assistant is the least one. If one robot fails, the assistant role will be left unallocated. Our distributed role allocation algorithm is based on market mechanism which is valid for it can satisfy the highly dynamic and competitive environment. The algorithm will not cause the vibration problem in role allocation and it can detect team members' failure autonomously and then select appropriate role combination adaptively and allocate them, so it is robust [6]. After the role is decided, the robot will act according to the corresponding team formation and its own role just allocated.

We also develop a 3D simulation system for RoboCup MSL and the system is based on Open Dynamics Engine and OpenGL. The interface provided for robot software is the same as in real competition environment, so our robot program can be used in both real and simulation environment without any change of resource code. The simulation scene is shown in figure 4.

Fig. 4. The simulation scene of NuBot

4 Current Research Focus

So far, we have developed a RoboCup middle-sized team, which is a good test bed to do further research. Now, our main research focuses are listed as follows:

-**Robust robot vision:** The final goal of RoboCup is that robot soccer team defeats human champion, so robots will have to play outdoors sooner or later. In the middle-sized league competition of RoboCup 2006 due to a glass wall in the competition field the changeable natural light caused much difficulty in image processing for most teams. To resolve the problem we developed a linear classifiers based CLUT (color lookup table) classifying method to segment the image. Combining the HSI with YUV color space the CLUT can reduce the effect of illumination value to image segmentation. But it is not yet fully satisfactory, for the hue or chromatic value will change with the change of light conditions [7]. Therefore, more effective methods have to be developed to make robot vision adaptive to the change of light conditions.

-Perfect world model: One of the biggest difficulties for the real robot is that it has deficient and imprecise knowledge on environment and itself comparing to simulation league. Thus building an accurate world model is the basis of further research [8]. Our current simple world model has to be improved to include the velocity of ball, robot, obstacles and high-layer knowledge such as the state of competition, ball controller, and so on. In this way robot can intercept a moving ball, avoid moving obstacles, and pass ball to teammates.

-Multi-robot cooperation: Multi-robot cooperation holds an important place in AI and robotics research. In most RoboCup MSL teams it is not difficult for robots to coordinate their roles and positions, but it is still very difficult for them to do cooperation such as passing and intercepting between teammates. Due to the imprecise sensor information and the delay of the actuators, the result of simulation can not be applied in the real robot directly. Therefore lots of studies should be done to realize cooperation between MSL robot teammates, such as developing new cooperation architecture and dealing with time-delay problem.

5 Summary

In the past three years, we have done lots of foundation work to build up a good test bed NuBot team for research in multi-robot field. Now we are prepared to carry out some high-layer studies based on our previous work. Our current research focuses are in robust robot vision, building perfect world model, and multi-robot cooperation.

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