JiaoLong2003 Team Description

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Abstract. JiaoLong participates in RoboCup World Championships for the first time. Three robots of the same type and one goalkeeper robot are being designed and built. In this paper, the major techniques and results relating to image processing, control, sensor fusion as well as team cooperation are presented.

1 Introduction

The Robot World Cup Soccer Games and Conferences (RoboCup) are a series of competitions and events designed to promote the full integration of AI and robotics research. The robotic soccer provides a good test-bed for evaluation of various researches, e.g. mechanical engineering, behavior control, image processing, sensor fusion, multi-agent cooperation and machine learning [1].

This is the first time that JiaoLong team participates the RoboCup. However, Our team had participated 2002 Chinese Robot Competition (CRC'2002) in Shanghai, China and won the championship of the middle-size league [2].

This paper presents the employed hardware, namely robots and computers, and new approaches to control robots.

2 System Architecture

The main idea for designing the whole multi-robot system is that we view each robot as an autonomous physical entity, which can intelligently interact with dynamic, uncertain environment. He must be physically strong, computationally fast, and behaviorally accurate. Moreover, robot should have the ability to perform on its own without any off-board resources such as global, birds-eye view cameras or remote computing processors.

2.1 Hardware Architecture

The JiaoLong robots are constructed at the Institute of Automation and the Research Institute of Robotics of the Shanghai Jiao Tong University as part of a project to build autonomous mobile robots for the research and education on distributed multi-robot systems operating under dynamic and uncertain environment. Three robot players of the same type and one goalkeeper are built as shown in Fig.1. The hardware system consists of mechanical platform, control system, sensing system and communication system as shown in Fig.2.

Fig. 1. JiaoLong soccer robots

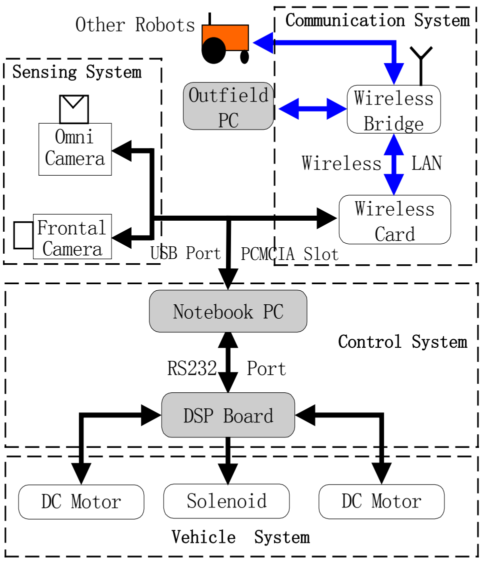


Fig. 2. Hardware architecture

Mechanical Platform: The mechanical body of each robot is in size of 45×45×60cm with two driving side-wheels and a caster wheel. Ball handling unit includes a motor-driving flipper and solenoid-driving kicker to be used to control and shoot ball.

Control System: A higher level computer and a microcontroller are used for behavioral control and motion control separately. The computer is a Compaq 2100 notebook PC with P4 1.9G CPU and the microcontroller is a DSP control board. Notebook and microcontroller are connected via a RS-232 serial link at 19.2Kbps. The whole system control cycle is 50ms.

Sensing System: Each robot employs two color cameras as its main sensors for ball, goal recognition and obstacle detection. Both Omni-directional and normal cameras are connected by USB1.1 to notebook PC for video stream transfer. The encoder-based odometer provides internal sensing ability.

Communication: The notebook PC also contains a wireless LAN interface that complies with the IEEE 802.11 standard. Every robot acts as a node in the LAN and has a wireless card that can transfer data at 11Mbps.

2.2 Motion Control

The TI DSP TMS320LF2407A is adopted as motion controller. Motion control board achieves desired movement according to the command from notebook PC, and feeds back odometry data and translational and rotational velocities.

Two side-wheels are driven by two 70W Maxon motors independently. A PID speed controller is used in closed loop to reject the effect of disturbance and modeling uncertainty of two wheel driving system to reach higher dynamic performance (Fig.3). The control frequency is 1KHz. The max tranlational and rotational velocity is 2 m/s and 360 °/s separately, the max acceleration is more than 2 m/s^2. The accumulated odometer can be on-line calibrated by notebook PC according to vision localization.

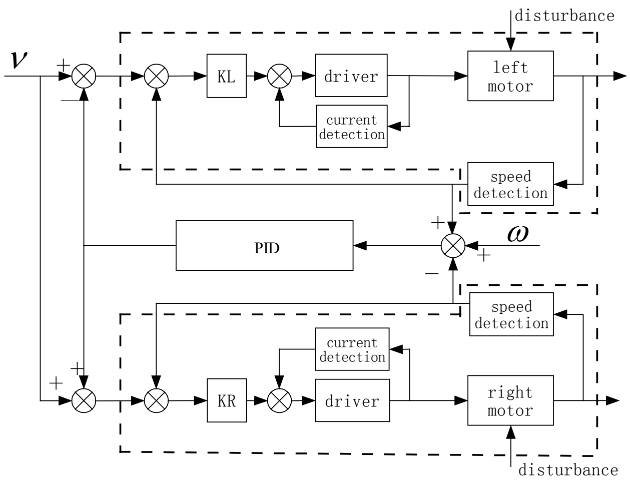


Fig. 3. Motion control structure

2.3 Vision System

Robot vision system is composed of omni-vision and frontal vision. The purpose of omni-vision is to observe the objects on the whole field. The other is fixed to frontal local area of the player for fine ball control.

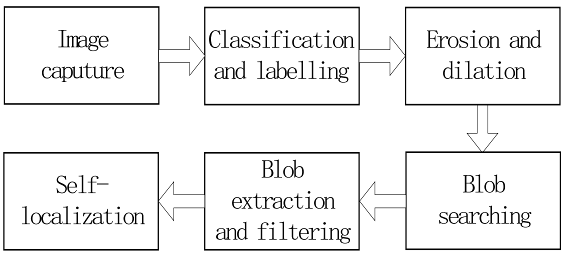
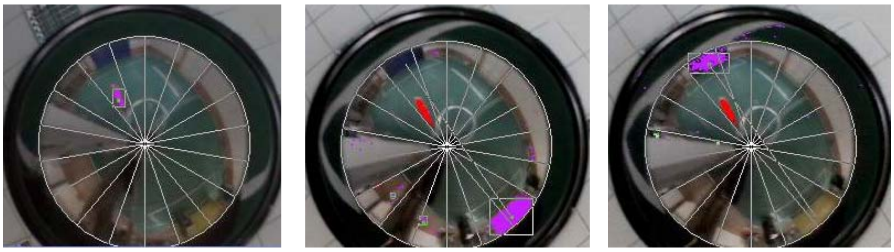


Fig. 4. Image processing algorithm

Fig. 5. Original image

Object Recognition: The task of whole vision system is to observe the environment around the player and determine direction and distance of ball, goals and self-localize according to the two goals. Then the information will be sent to behavior control and global environment model. The image segmentation for object tracking is based on the blob algorithm. The frame rates are the same 14 fps for both vision systems. The omni-vision interpret higher resolution image (320×240 pixels) than frontal vision (160×120 pixels). The image processing algorithm of Omni-vision is shown as Fig.4.



(a) Ball tracking (b) Yellow goal tracking (c) Blue goal tracking

Fig. 6. Image segmentation and object localization

The original image captured by omni-vision is shown as Fig.5. The Fig.6 (a), (b) and (c) show the blob corresponding to ball, yellow and blue goal, respectively. The object is labeled by purple pixel surrounded by a rectangle. The erosion and dilation are introduced to eliminate image noises.
Self-localization: After object recognition, vision system will determine the direction and distance of the tracked objects with corresponding blob position in image. So players can realize self-localization based on the positions of two goals. If the player can't observe two goals at the same time, it can still self-localize with the odometer data and the position of one goal.

2.4 Software System

For developing open and extendable control software on Windows OS, an Inter-process Communication (IPC) mechanism is introduced to realize distributed software design (Fig.7).

The whole software consists of multiple processes. The decision process (main process) is located in the core. Each device including omni vision, frontal vision and outfield computer has an independent process, which exchanges data with main process via Socket communication.

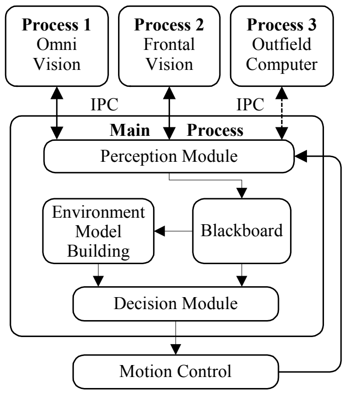


Fig. 7. IPC-based software design

3 Behavioral Control

The high-level behavior control is designed according to FSA and Motor Schema theory [3, 4]. Every robot has the following basic behaviors: Dribble_Ball, Move_To_Goal, Search_Goal, Shoot_Ball and Avoid_Obstacle. Multiple behaviors fusion is realized by summation of activated behavior vectors.

Behavioral control structure is shown in Fig.8. From top to bottom, there are three layers: strategic layer, state layer and behavior layer. The top layer assign role to robot and decide current team state according to game condition. The medium layer decomposes current task and activates related behavior set. The bottom layer fuses all behavior outputs and sends command to motion controller.

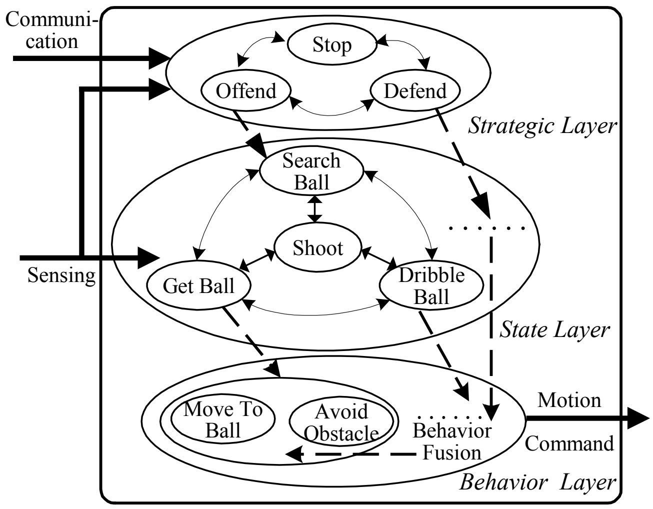


Fig. 8. Behavioral control structure

4 Multi-robot Cooperation

Multi-robot interaction through communication and observation provides the information basis for high team performance. Our team realizes team cooperation in both perception and action aspects.

4.1 Team Architecture

Our robot team takes hierarchical architecture as shown in Fig.9. The outfield computer makes decision on the global task level as the team coordinator, and each robot executes its own sub-task assigned by team coordinator. Via wireless LAN the team players submit their model parameters and states to the team coordinator periodically, the outfield computer fuses out global model and update the local model of each robot. Meanwhile, the new role assignment and team state will be sent to all robots according to global model. The information sent to outside computer includes the robot's position and heading, current role (forward, midfield, defender and goalkeeper) and state (Get Ball, Dribble Ball, Search Ball and Shoot) and ball position.

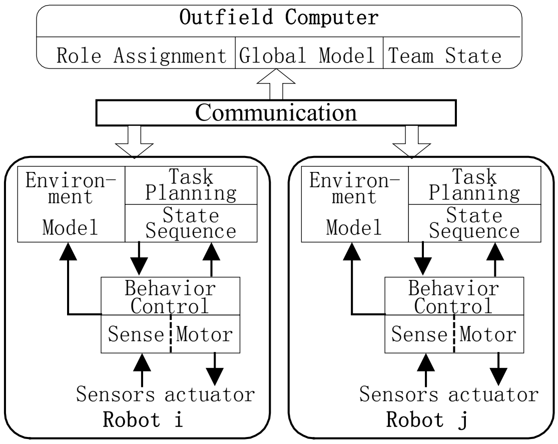


Fig. 9. Hierarchical team architecture

4.2 Distributed Sensor Fusion

Focusing on improving perception accuracy and completeness, we apply inter-robot communication and distributed sensor fusion method to robot soccer game. Our method provides two improvements as follows:

Increasing Sensing Completeness: Individual mobile robot can only observe local area at any time. In general, sensors such as cameras have a limited field of view, so an agent cannot sense all objects around the filed. Based on our sensor data sharing method, a global field model is maintained in the outfield computer, which communicates with all filed robots.

Increasing Sensing Accuracy: Generally, the data given by robots about the positions of objects in the dynamic environments is not accurate, even false. But if the information from all robots is collected and processed effectively, the robot will be provided with more accurate information. A priority-based fusion method is adopted in the outfield computer. The robot is more close to the object the higher priority value will assign to its sensing data.

Case Study: Two case studies have been done to show the above approach. Firstly, based on data sharing, one robot can get ball position from others although he cannot see the ball. This can be seen from Fig. 10(a). Some obstacles stay around robot 1 and block his field of vision, but he can get the ball position from robot 2 via communication. Secondly, let two robots perceive ball simultaneously, but the ball positions given by two robots are different due to sensing uncertainty. This can be seen from Fig. 10(b). The fusion module will choose the data given by the robot that is nearest to the ball as the ball position, and then send it to all robots.

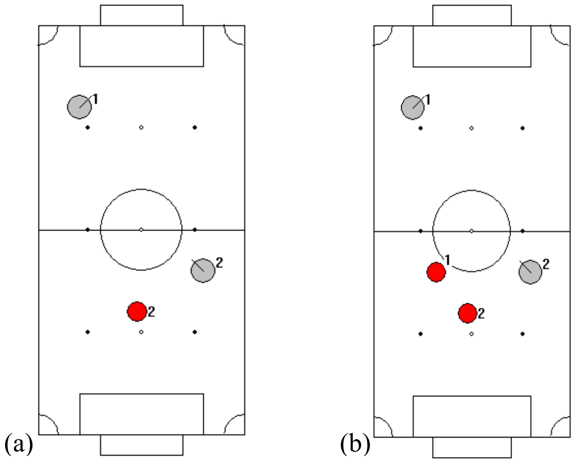


Fig. 10. Case study of multi-robot sensor fusion

4.3 Behavioral Cooperation

For team cooperation, we take a dynamic role assignment strategy. At the beginning, every robot has an appointed role. But the role can vary according to the team state. The team state is determined by information supplied by all team robots and made by outfield computer. Besides, an individual area is allocated to every defined role. That is, a certain role can only act in a special area. At the same time, a dynamic area assignment strategy is applied. This means the area partition is not fixed but varies according to the ball position. Through these two dynamic strategies, we can realize robots coordination and cooperation.

5 Conclusion

In this paper we presented the design of JiaoLong for RoboCup2003 competition. From the viewpoint of hardware, all JiaoLong robots are equipped with two cameras for field mapping and localization. For software, a hybrid architecture with distributed sensor fusion is adopted to realize cooperative perception and multi-robot action coordination. Considering the hardness of hand programming of robot behavior, a learning method both in state layer and behavior layer are now studied on.

In the CRC'2002 competition, our robots behaved well and won the game. Now, we have improved our robots both in hardware and software.

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