RoboDragons 2009 Extended Team Description

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1 Introduction

The RoboDragons team of Aichi Prefectural University has been doing its activity for 11 years this year. At first, the team started as a joint team with Chubu University in 1999. The name of the team at the time was Owaribito. In 2002, however, we newly started our team as the team consisting of people of Aichi Prefectural University[1] and our team was renamed RoboDragons. In 2004 and 2005, we made a joint team with Carnegie-Mellon University to brush up the robot system. The name of the team was CMRoboDragons. Meanwhile, we won the 1st place 4 times in the Japan open and won, in the RoboCup World Competition, the 3rd place in 2007 and the 4th place in 2004 and 2005.

Our current robots are the fourth generation ones in our Labs and the soccer software is an improved one which was originally developed by CMU during 2004 and 2005 when we had the joint team. Many technical elements of the robots are introduced the technology developed by the strong teams such as Cornell University, Free University of Berlin, Carnegie-Mellon University and so on, however, the solenoid driving circuit which realizes the powerful kicking is our original one. The soccer software is improved for our purpose by implementing the various strategies and the cooperative play skills such as 1-2-3 shoot.

In this paper, we describe the RoboDragons system in detail.

2 RoboDragons Team Members

The members and their roles of RoboDragons 2009 are as follows,

- Junya Maeno(Strategy and Tactics, Team Leader)
- Hiroki Achiwa(Vision and Mechanics)
- Junya Tamaki(System Design)
- Saori Suzuki(Tactics)
- Tatsuya Moribayashi(Vision)
- Kazuhito Murakami(Supervisor)
- Tadashi Naruse(Supervisor)

[1] The reason is that students of both universities had grown up to be able to develop their robot system theirselves in each university.

3 RoboDragons system overview

In this section, we give an overview of the RoboDragons system.

RoboDragons system consists of 5 robots, a host computer, cameras, a video capture board and a communication device(modem). Table 1 shows the summary of the system.

Table 1. RoboDragons system overview

Robots	Products of SMATS Inc.
Host Computer	
CPU	Athlon64 X2 4200+
Memory	512MB
OS	Debian GNU/Linux
Language	C++
Compiler	gcc version3.3
Cameras	
Body	Panasonic DVR-310
Lens	RAYNOX HD-5050PRO
Video Capture Board	Philips SAA7133 based
Modem	Futaba FRH-SD03T

Figure 1 shows an outward of the robot with and without the robot cover. Each robot has 4 omni-wheels each of which is driven by a DC motor with an encoder, kicking devices which realize a straight kick and a chip-kick, a dribbling device, and computer boards that controls the robot. Detailed description of the robot is given in the next section.

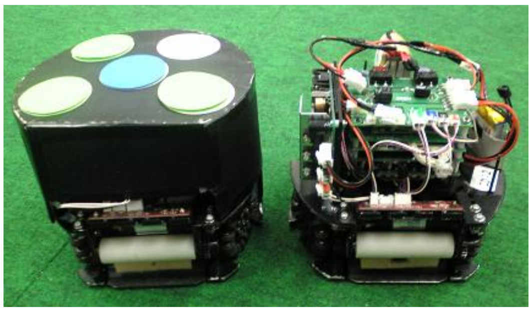


Fig. 1. Robots

The robot control program for the RoboCup soccer is developed by using the C++ programming language under the Debian GNU/Linux. The basic program was developed when we had jointed with CMU in 2004 and 2005. After the joint team was over, we have been improving the program ourselves. However, the basic framework of the program have not been changing since 2005, namely the modules of the program are an rserver, a soccer, a view and a vlog, as shown in the dotted line of figure 2. The rsever has a vision and a radio submodule. The soccer and view modules have a common world submodule which contains a tracker submodule. The role of each module or submodule is as follows,

rserver The rserver takes an interface with other modules and the outer world, i.e. controls the whole system.
soccer The soccer decides the action of each robot under the given strategy.
view The view is a GUI module. It communicates with an operator. It also initializes the system state at starting time.
vlog The vlog logs various data such as robot position, velocity, which are necessary for the analysis after the competition.
vision The vision processes the captured images and detects the position of robots and a ball.
radio The radio makes a robot command packet and sends it to the robots through the radio device.
world The world computes the velocity of each robot and a ball and manages the history of the movement of each robot.
tracker The tracker is a submodule of the world module and predicts the positions of robots and a ball at 5 frames ahead by using the history.

The modules are invoked as processes and the communication between modules is performed by the UDP communication.

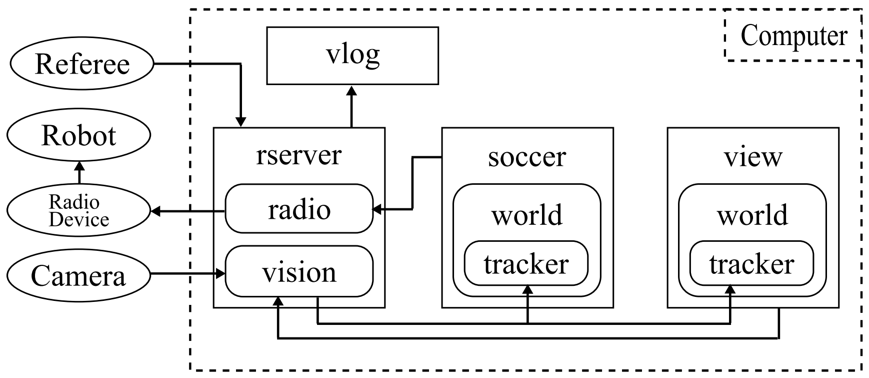


Fig. 2. Configuration of the RoboCup soccer program

4 Robots

In this section, we discuss our robots in detail.

4.1 Robot hardware

Dimensions of robot The robot can be packed in the cylinder with dimensions of 145 *mm* height and 178 *mm* diameter. To protect the internal circuit boards and mechanical devices, the robot is covered by the cardboard shown in figure 3. To reinforce the cardboard, the plastic sheet with 1.5 *mm* thickness is glued on the cardboard.

Drive unit The robot has 4 wheels each of which is drived by a DC motor. The wheel is so called an omni-wheel. Figure 4 shows the omni-wheels attached to the robot.

The DC motor driving the omni-wheel is Maxon's "RE-max 24" with encoder unit. The source voltage of the motor is 15 V. The motor also has a pinion gear with 12 teeth and the omni-wheel has a gear with 95 teeth so that the reduction ratio is 1 : 7.92. The diameter of the omni-wheel is 60 mm and the omni-wheel has 15 small tires in circumference. The diameter of the small tire is 13 *mm*.

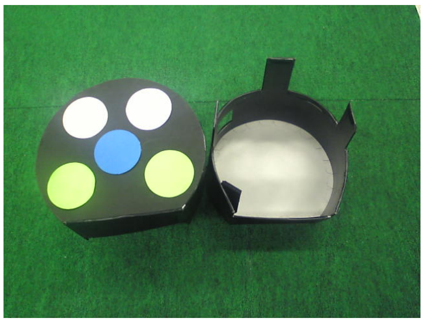


Fig. 3. Robot cover

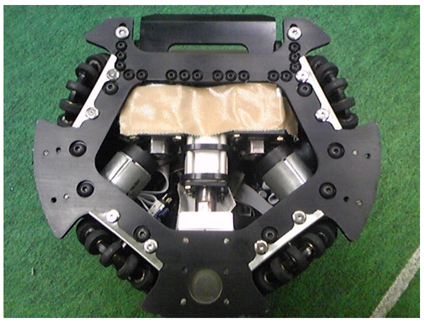


Fig. 4. Omni wheel

Kicking device The kicking device consists of solenoids, kick bars, and a voltage booster.

Solenoids: Three solenoids are built in the robot, one is for a main kicker and two are for a chip kicker. These (coils only) are shown in figure 5 and figure 6 shows the solenoids built in a chassis. In Fig. 6, the solenoid at the center is used for the straight kicking (main kicker) and the two small solenoids are used for the chip kicking.

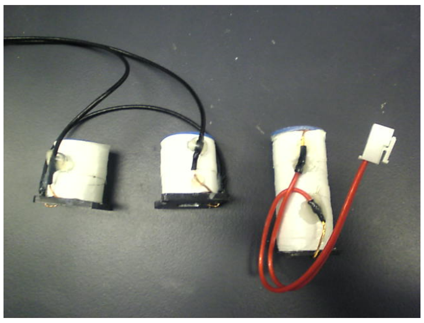


Fig. 5. Solenoids

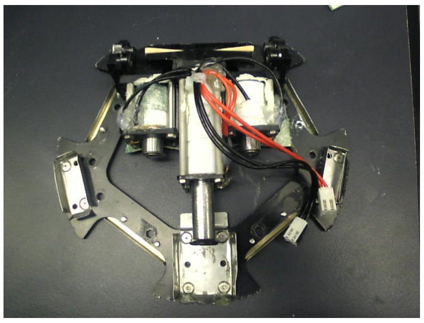


Fig. 6. Chassis

The coil of the large solenoid is made winding the 0.7 mm^{ϕ} enamelled wire on a polyacetal (POM) cylinder in 8 layers. The dimensions of the cylinder are 13 mm in inner diameter, 26 mm in outer diameter and 55 mm in length. The stroke of the solenoid is 30 mm and enables the kicking a ball with speed of 9.5 $msec$ under the ideal conditions.

Two small solenoids are connected in series to make a chip kicker. The coil of the small solenoid is made using the same material with the large one. The dimension of the cylinder is 13 mm, 26 mm and 27 mm, respectively. The stroke is 7 mm and it can kick the ball with flying distance of 2 m and flying height of 1 m.

Each solenoid uses the spring to pull back the plunger.

Kick bar: Figure 7 shows the kick bar. 7075 aluminum alloy which is light and hard is employed for the kick bar. Moreover, V-shaped ABS plastic is attached to the aluminum kick bar as shown in figure 8. This helps to kick the ball to the direction perpendicular to the kick bar within the accuracy of 5 degree.

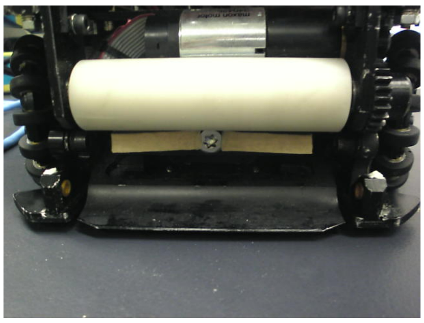


Fig. 7. Kicking device

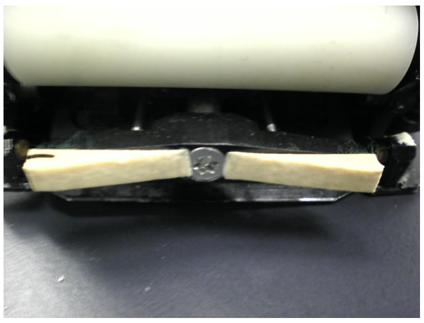


Fig. 8. Attachment of V-shaped plastic

Voltage booster: The voltage booster is a kind of DC-DC converter. It converts 15 V DC input voltage up to 250 V DC output voltage. Output voltage is adjustable between 150 V and 250 V. A booster circuit is shown in figure 9. The chopper circuit using a choke coil is a heart of the voltage booster. A PIC controls the chopper circuit. Large capacity condensers are used for keeping the high voltage output. Total capacity is 4500 μF. The voltage sensing circuit controls the output voltage. 2 solid state relays are used as the switches to drive the solenoids. These relays are controlled exclusively by the PIC. The charging time of the condensers is about 2 *sec* when the output voltage is 200 V.

The voltage booster is shown in figure 10

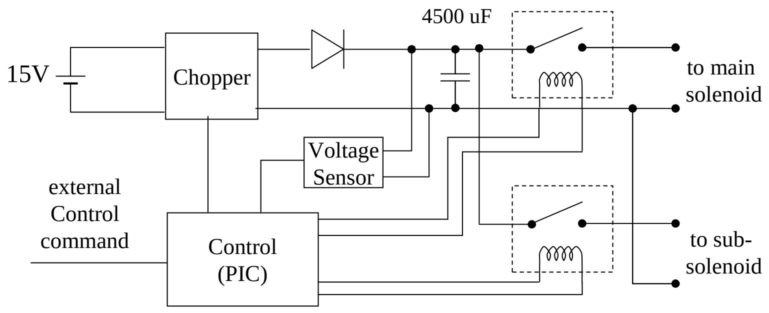


Fig. 9. Voltage boost circuit

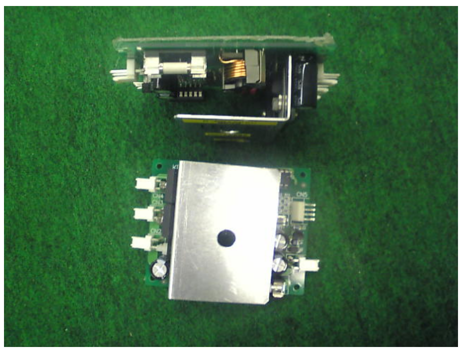


Fig. 10. Voltage booster

Dribbling device A dribbling device of the robot has been achieved by combining the dribble roller, the motor and the gear. Figure 11 shows the dribbling device.

The dribbling device uses a Maxon's "RE-max 21" motor with an encoder and a planetary gear. The reduction ratio of the gear is 1 : 3.8. A pinion gear attached to the motor has 30 teeth and a gear attached to the dribble roller has 24 teeth. Therefore, the net reduction ratio R is given by,

$$R = R_m \times R_g = 3.8 \times \frac{24}{30} = 3.04, \tag{1}$$

where, R_m is the reduction ratio of the planetary gear and R_g is the reduction ratio of the pinion gear and the gear on the dribble roller.

The dimensions of the dribble roller are 20mm in diameter and 73mm in length. The material of the dribble roller is a alminum shaft with silicon rubber of 4mm thickness on the face of the shaft.

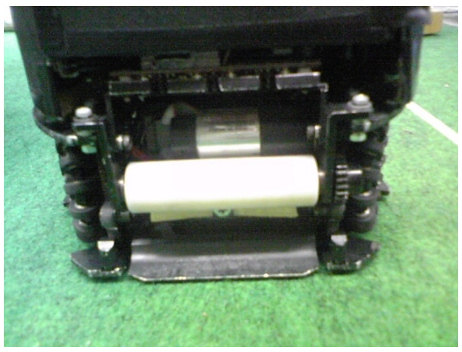


Fig. 11. Dribble device

Communication unit Our wireless communication is a spectrum diffusion communication on the 2.4 GHz band. Futaba's wireless modem "FRH-SD07T" is used for the purpose. It is shown in figure 12. The modem has several communication modes. We use a "direct mode" which can send the messages the least delay among the various communication modes. A pair of the FRH-SD03T and the FRH-SD07T realizes the communication between the host computer and the robot(s).

Proximity sensor unit The proximity sensor is attached above the dribbling device and it detects the ball just in front of the dribbling device. Figure 13 shows the proximity sensor viewing from upper side and lower side. Also, see Fig. 3

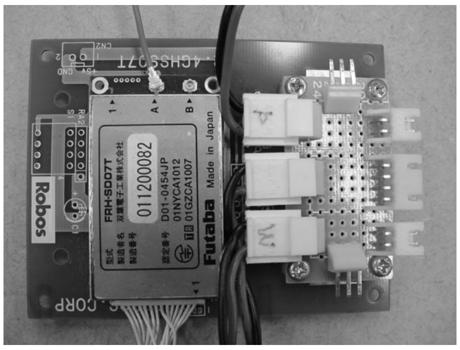


Fig. 12. Communication system

for the sensor attached to the robot. The heart of the sensor is three infra-red light emission diode (LED) and photo diode pairs. The irradiation angle of the LED is about 15 degree. When one of the three photo diodes gets the reflected infra-red ray more than a preset threshold value, the sensor outputs the signal.

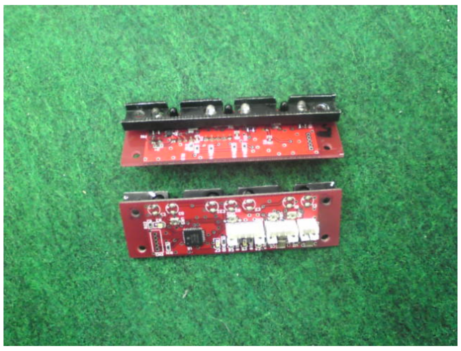


Fig. 13. IR

Control unit A control unit of robot is a board computer. It consists of four print circuit boards. It is shown in figure 14[2]. These boards include a power supply board (top), a CPU board (center) and IO boards (bottom two). The CPU is Hitachi's SH2 processor. SH2 has abundant peripheral circuits in it and makes the compact implementation of the control unit possible. The memory is

[2] There are five boards in the figure. However, one of them (the second board from the top) is the communication board.

composed of Flash ROM(1MB) and SRAM(1MB). The IO boards have power transistors that can drive the motors and they also have interface circuits with the motors driving wheels and dribble roller, and the proximity sensor.

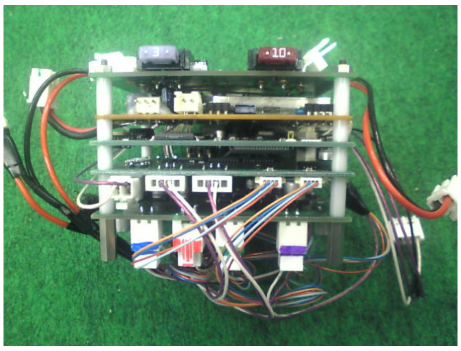


Fig. 14. Processor boards

Batteries Power source is two lithium polymer batteries. One is 7.4 V, 2100 mAh battery and it supplies the power to the control, communication and sensor units. The other is 14.8 V, 2170 mAh battery and it does to the motors. Figure 15 shows these batteries.

Fig. 15. Batteriesitop: 7.4 V battery, bottom: 14.8 V batteryj

4.2 Software on robots

Here we describe the software on the robot. The program is written by the C programming language. A tiny real time monitor is used. This monitor program is offered by the SMATS Inc. It provides multi-process environment.

Robot control program consists of three modules each of which is invoked as a process. They are communication, command and motor control modules. Figure 16 shows a data/signal flow among modules and peripheral units.

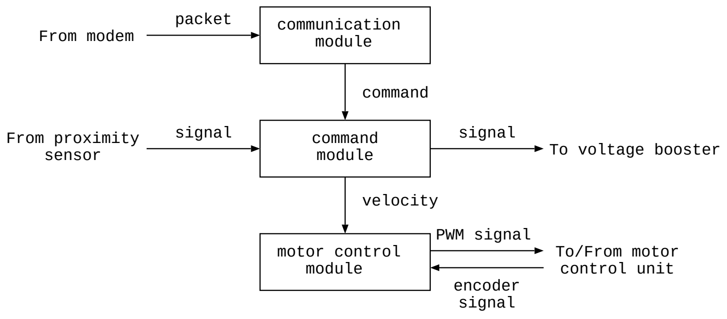


Fig. 16. Data/signal flow

Robot command is sent from the host computer to robots by a packet every 1/60 seconds using asynchronous serial communication. Since the communication speed is 19200 bps in our system, it is possible to send 32 bytes data in 1/60 second if only start bit and one stop bit are used as control bits. Therefore, Our packet is consisted of 32 bytes[3] as shown in figure 17. The packet is broadcasted to all robots. The packet has error correcting code (ECC) to make reliable communication possible. We use the Humming code as the ECC.

The communication module receives the packet and extracts the command of its own. If error is detected, the packet is discarded. As far as the error is not burst error, the discard of packet is a good alternative[4]. Extracted command is sent to the command module.

In the command module, the velocity of each wheel is calculated from the vel, dir and rot value (see Fig. 17) and calculated result is sent to the motor control module. The kick and dribble command is executed, as well.

In the motor control module, the PID control is performed. This is done by using the target velocity given by the command and the current velocity calculated from the encoder pulses. The motor drive control is done by the PWM control.

[3] The command cycle synchronizes with the camera cycle which is equal to 59.94 frames per second. Therefore, the command can send without any problem.

[4] There are no such errors experienced in recent years competition.

```
class SerialCommand{
  public:
    uint8_t vel;    // Velocity [unit: cm/s]

    uint8_t dir;    // Direction [unit: 2*pi/256 rad]

    uint8_t rot;    // Rotation velocity [unit: 2*pi/60 rad/s]

    uint8_t var;    // kick and dribble command
                // b0-b1: kick condition
                //       0 : No kick
                //       1 : kick when center senser reacts
                //       2 : kick when any sensers react
                //       3 : kick immediately
                // b2-b3Eb7: Selection of kicker
                //       0 : No kick
                //       1 - 4 : Main kicker (1: weak ... 4: strong)
                //       5 - 7 : Chip kicker (5: weak ... 7: strong)
                //             : Main and chip kickers are used exclusively
                // b4-b5: Dribble
                //       0 : No dribble
                //       1 : Reverse rotation
                //       2 : Weak normal rotation
                //       3 : Strong normal rotation

    uint8_t ecc01;    // b0-b3: ECC of vel
                      // b4-b7: ECC of dir

    uint8_t ecc23;    // b0-b3: ECC of rot
                      // b4-b7: ECC of var
};

struct SerialPacket{
  uint8_t header0; // 0x80
  uint8_t header1; // 0x0D
  SerialCommand robot[5];
};
```

Fig. 17. Packet configuration

5 Vision system

The vision system consists of the calibration system and the image processing system. The calibration system calibrates a coordinate system and a color system before a game starts. The image processing system detects the positions of the ball and robots from the images given by two cameras set at over the field, and then merges the positions. The merging process is necessary since there is overlapped area in two camera images. The merged positions are sent to the world system(information management system). Figure 18 shows the dataflow of the main modules of our vision system. This system have been developed based on the CMVision(Version2.1a) system of Carnegie Mellon University.

In this section, 5.1 describes the calibration system. 5.2 5.6 describe the detection process for given images, and 5.7 describes the merge process of positions. See section 3 for the hardware description of the cameras and the capture board.

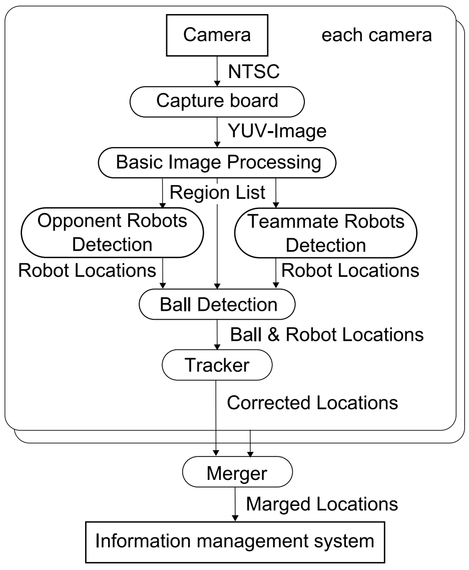
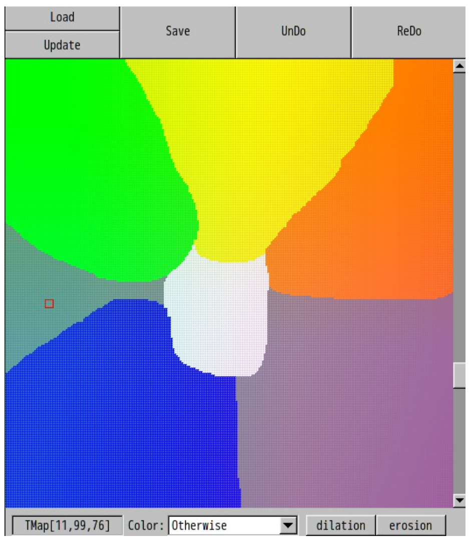


Fig. 18. Vision System Overview



TMap[11,99,76] Color: Otherwise

Fig. 19. GUI for ColorCariblation

5.1 calibration System

Color calibration In the image processing, we have to extract the ball and the teammate and opponent robots from the captured images which are YUV images. The ball is characterized as an orange area and the robots are characterized by a team marker and sub-markers. The team marker is characterized as a yellow or blue area and submarkers are characterized as light green, light pink, cyan and white area. These colours are suitably distinguished.

To do so, we use a colour lookup table. The lookup table is a 3 dimensional array corresponding to Y, U, V axes whose resolutions are 16, 256 and 256 levels respectively. The element of the array shows colour id number. We give each element of the array the suitable colour id number manually using the paint tool. An example is shown in figure 19. It shows a U-V plane. Y value can be changed by the scroll bar at right side. There are several regions in Fig. 19. A region corresponds to some colour. Using the lookup table, the captured YUV images are classified into regions having colour id numbers.

Coordinate calibration We obtain the camera model used for the projective transformation that converts the image coordinates into world coordinates.

First, we put calibration markers on the designated positions on the filed. These positions are the positions in the world coordinate. Then, we get the field images and obtain the coordinates of markers on the images. Finally, camera parameters are updated manually by using world coordinate and image coordinate and initial parameters. These parameters are obtained by the conjugate gradient method of Fletcher-Reeves to minimize the error of world coordinate and logical coordinate. We use the GNU Scientific Library to calculate the conjugate gradient method. The camera model is generated using the parameters obtained here.

Other Configurations We make a mask image to avoid the miss detection by objects existing at the outside of the field. The image is made using the dedicated paint tool. The size of the image is the same as the size of the captured image. The masked area is excluded from the image processing.

A color histogram around the team marker of opponent robot is made in advance. This is used to improve the detection accuracy of opponent robots.

5.2 Basic Image Processing

The capture board control program is written by using the Video4Linux(V4L). The ring buffer is made on the memory of the capture board. This makes possible to get the latest image when the image processing program attempts to get the image.

In the basic image processing in Fig. 18, the captured images are classified into regions having colour id numbers by using the lookup table given in section 5.1. To the resulting images, labeling processing is done. For each colour id number, the labeled components with the same id are listed in descending order of the size of the area as shown in figure 20. We call this list a RegionList.

5.3 Opponent Robots Detection

There are two common processes for object detection. First, we use confidence value. The confidence value shows how the detected object is reliable as the

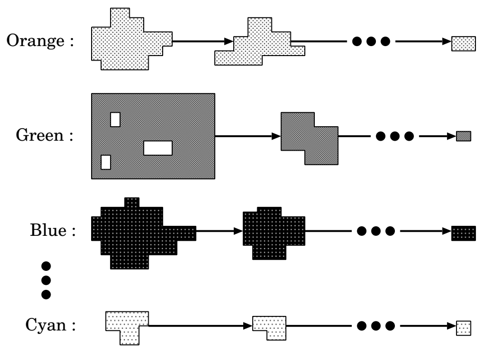


Fig. 20. Region list

object itself. The value ranges from 0 (least reliable) to 1 (most reliable). Second, the transformation from image coordinates to world coordinates is calculated through the camera model obtained in the section 5.1.

Operators can give parameters needed to detect the robots through the GUI. The parameters are a team colour, a robot model, a number of robots and so on. The robot model is a configuration of submarkers. In our robot, 4 circular submarkers are arranged like the feathers of a butterfly. So we call the robot model a butterfly model. (See Fig. 1.) Use of robot model helps to increase the reliability (confidence value) of the detected robots. For the opponent team, if it doesn't use a butterfly model, only team maker is used to detect the robots. Namely, in the RegionList for blue or yellow colour, regions with designated width, height and area are chosen as the candidates of opponent robots, and the color histogram of region around the team marker given in section 5.1 and that of a candidate region is compared. If these histograms are similar, then the candidated region is remained as a team marker region and the confidence value is calculated. The confidence value is 1 if the area A of the region is between TH_{min} and TH_{max}, otherwise, it decreases as the $A - TH_{max}$ increases or $TH_{min} - A$ increases. These threshold values are decided by the experiment before a game starts.

The opponent robots are detected as top N regions that have high confidence values, where N is a number of opponent robots (usually 5). At the same time robot positions (world coordinates) are computed as a gravity center of the region.

Robot ID is decided by using the GreedyMatching algorithm. This algorithm computes the Euclidean distance between the detected robot position and the positions of all robots 1 frame ago and decides the ID of the detected robot as the ID of the robot in the previous frame that has the minimal distance.

5.4 Teammate Robots Detection

For teammate robots, the detection is done as follows. First, choose the candidates of team marker regions from the RegionList and compute their confidence value.

Since the teammate robots use the butterfly model, the candidates of submarker regions are selected from the RegionList according to the using submarker colours (white, light green, light pink and cyan). The confidence value and the position of each candidate submarker region is computed.

For each candidate of team colour region, the submarker candidate regions that exist within the circle whose center and radius are center position of team colour region and robot size (namely 9 cm) are searched. If 4 submarker candidates are detected within the circle, the circular region is teammate robot and submarkers are ordered and numbered as shown in figure 21. Fig. 21 shows the positions of a template pattern. Detected pattern is a rotated pattern of the template pattern. The rotation center is an origin of x-y axes. This rotation angle gives the direction of the robot. To reduce the detection error, the rotation angles of all submarkers are computed and their mean value becomes the rotation angle of the robot.

The position of the teammate robot is computed using the team marker and the submarkers. Confidence value is also computed using these markers. The confidence value is 1 if the error E of the detected submarker positions from the robot model is less than TH, otherwise, it decreases as the $E - TH$ increases. The threshold value is decided by the experiment before a game starts.

The ID number of a robot can be decided using table 2. We use the light green and light pink submarkers. When 4 submarkers are numbered from 0 to 3 and colours are numbered from 0 to 3 as shown in Fig. 21, the colours of ordered submarkers give the ID number of robot as shown in table 2.

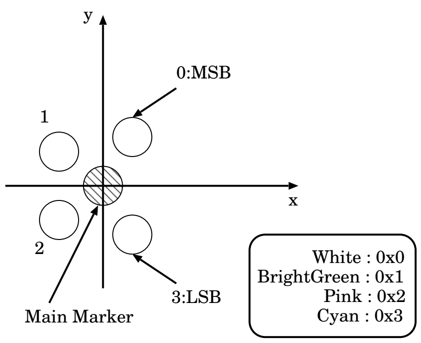


Fig. 21. template of the robot model

Table 2. ID table

Robot ID	Color Pattern
0	0x1111
1	0x1112
2	0x1121
3	0x1122
4	0x1211

5.5 Ball Detection

In the detection of the ball, for each candidate of the ball region in the RegionList for orange, the width, height and area size of each region is checked and the confidence value is calculated. Then, the best matched region is selected as the ball region. The confidence value is calculated in the same way as that of opponent robots.

However, orange regions are often detected around the boundary between the yellow marker and light pink submarkers. For such regions, the confidence value is lowered.

5.6 Tracker

The position data of detected objects (robots and a ball) may have an error. Therefore, we use the Kalman filter to compensate the positions and velocities of the objects. For robot objects, the directions and angular velocities are compensated too.

Assuming the linear uniform motions for objects[5], the Kalman filter equations are computed. We assumed that the process noise and the observation noise are Gaussian white noise. Thus, the position data at the current frame are compensated.

If position data are failed to detect at the current frame, the estimated position data from the past position data by the Kalman filter are used.

5.7 Merger

Multiple cameras (in our case, 2 cameras) cover the whole field for objects detection. There are overlapped areas on the field that are covered by 2 or more cameras. When there are objects in such an overlapped area, they are detected from 2 or more images of the cameras. In such case, we have to select the suitable one from the several candidates of one object. The merger does this.

Basic idea is to select the candidate of object with highest confidence value. For the teammate robots, the submarkers give enough information to decide robot ID. So, it is easy to select the object with highest confidence value. For

[5] For a short time span, this assumption is reasonable.

the opponent robots, the GreedyMatching algorithm is used to decide the robot IDs again for all robots detected in all images. Then, the robot with highest confidence value is selected if there are robots with the same ID.

The merged ID data are sent to the world system.

6 World system

The world system is an information management system used with the soccer system (strategy system) and the view system (GUI system). The world system processes the data to be used in the soccer system and the view system based on the data obtained from the rserver system. In this section, we explain the data used in the world system, the view system and the simulator system.

6.1 World system information

Location information
: The world system obtains the location data of each robot and ball from the vision system and the tracker system, and then estimates the location data at 5 frame later based on the model of linear motion. Consequently, the world system has three location data from (1)the vision system, (2)the tracker system, and (3)the world system.

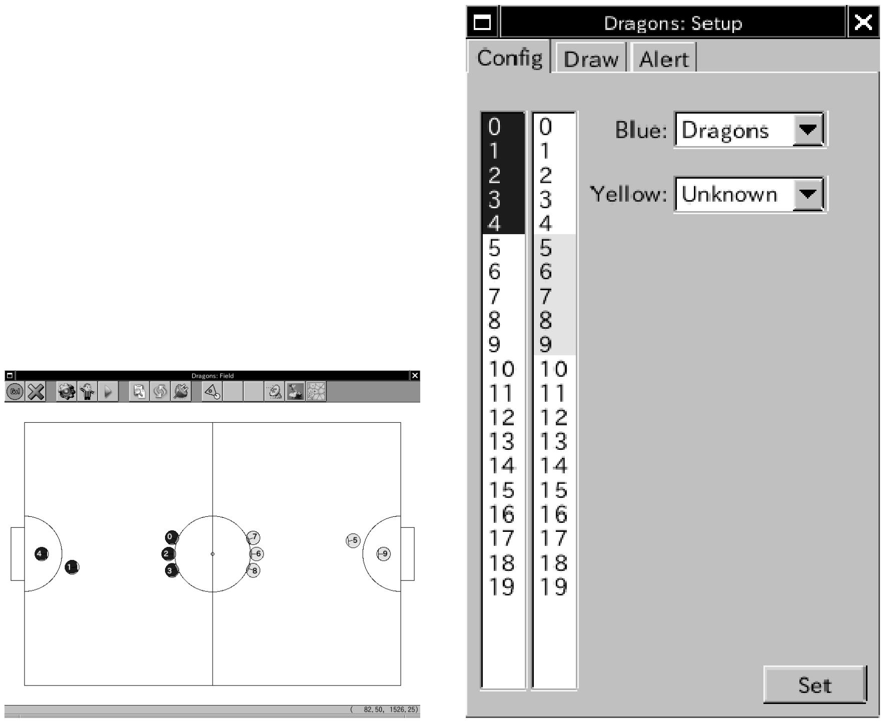
Obstacle information
: The obstacle information includes the areas of opponent and own team's defense, the area of field data, opponent and teammate robots and ball. These data are used to avoid the collision.

6.2 View system

The view system displays the game status, internal data or the parameters of the system for the user. This system partially utilizes CMDragons' GUI system [1].

Figure.22(a) shows the "Main Window" of the view system. The "Main Window" displays the field image on the center of it and the buttons to start each component system. Figure.22(b) shows the "Setup component". We explain some of typical components as the example.

1. Setup component
   Here, it sets up fundamental information. It can change the number of the robot, and display velocities of robots or ball on the "Main Window".
2. Referee Box component
   This component operates the robot by generating referee signals by the user. This is used for the check of robots.
3. Operating check component
   This component sends the command to the robots. For example, this is used for the operation of the moving from the edge of the field to an other one.



Blue: Dragons

Yellow: Unknown

(a) Main Window (b) Setup component interface

Fig. 22. GUI System

6.3 Simulator

In RoboDraons system, the simulator system is included as an alternative of the rserver. By using this simulator, we can operate our system in near real environment.

The simulator system obtains some data which is robots and ball location and velocity, and game state. According to the robot operation data from the soccer system, it processes robots' movement, kicking and collision of robots and ball, and then updates robots and ball location and velocity. Furthermore, according to the referee command from the view system, it updates game state. Moreover it can change the location and velocity of robots and ball by operating from the view system.

Generating data is sent to the world system same as the rserver.

7 Soccer system

The soccer system selects a strategy based on the information given by the world system, and assigns the roles in order to achieve the strategy to each teammate robot. Each robot receives the operation command by radio. In this section, we describe our soccer system.

7.1 Strategy selection

Strategy selection index
: The soccer system selects a strategy by the basis of indexes shown in Table.3. A strategy is composed of some indexes. Each index is generated by the world system.

Play file
: One play file shows one strategy. It is described by the text on our system. A play file includes strategy name, the condition that the strategy is selected, the condition to abort it, the condition to achieve it, necessary number of robots, and roles(skills) for each robot and priority of each role.

Play book file
: In play book file, play files' name and its priority are described. Only the soccer system can select play files described in play book file.

Strategy selection
: The soccer system selects play files described in play book file based on the strategy selection indexes. In many cases, only one play file is selected. When some play files are selected, then high-priority one is selected.

Assignment of role of each robot
: Our system calculates costs used for assignment of role of each robot. In many cases, the cost is distance between current location of the robot and target location of the role. The combination of roles and each robot which minimizes total of costs is selected. Only the goalie is excepted because it must be selected previously.

Table 3. strategy decision index

Index Name
Game on
Game off
Our team KickOff
Our team Indirect FreeKick
Our team Direct FreeKick
Our team Penalty Kick
Opponent team KickOff
Opponent team Indirect FreeKick
Opponent team Direct FreeKick
Opponent team Penalty Kick
Opponent team Penalty Kick
Our team attacking
Our team defending
Loose ball
Ball is in Opponent side
Ball is in Our side
Ball is in around center
Ball is near Opponent goal
Ball is away from Opponent goal
Ball is near Our corner
Ball is near Opponent corner
Our team winning
Our team losing
Our team winning big
Our team losing big

7.2 Role and skill

Role described in play files is composed of some skills. One skill is one class in our system, and it has function for calculating target location and velocity of the robot based on the data from the world system. Then, the soccer system obtains them from skills, and sent target location and velocity, and obstacle data to the path generation. The following shows some of the skills often used in the game.

1. Goalie skill
   [purpose] to defend our goal
   [number of robots] 1
   [algorithm]

```
if(opponent PenaltyKick)
    then move to the location on the extended line of opponent
         kicker direction
else if(the ball is in our DefenseArea)
    then move to behind of the ball and push it out to the
         outside of DefenseArea
else if(the ball is in front of the robot)
    then chip-kick the ball
else if(the ball moves to the goal)
        if(goalie can move to intercept point earlier
           than any other teammates)
            then intercept the ball
        else
            then defend our goal with defenders cooperatively
else
    then defend our goal with defenders cooperatively
```

2. Defender skill
   [purpose] to defend our goal
   [number of robots] 1˜2
   [algorithm]

```
if(the ball is in our DefenseArea)
    then wait around our DefenseArea
else if(the ball is in front of the robot)
    if(opponent robot exists around the line which is
       connected from the defender to the ball)
        then chip-kick the ball
    else
        then straight-kick the ball
else if(the ball moves to our goal)
    if(defender can move to intercept point earlier
       than any other teammates)
        then intercept the ball
    else
        then defend our goal with other teammates
```

```
else
    then defend our goal with other teammates
```

3. Marking skill
   [**purpose**] to block shoots and passes
   [**number of robots**] 1˜2
   [**algorithm**]

```
Let X be the opponent robot which is nearest to the ball
if(opponent corner kick)
    then move between X and opponent robot which is nearest to
         our goal
else if(opponent throw-in)
    then move between opponent robot which is nearest to
         our goal and center of our goal
else
    then move on the line connected from X to the ball
```

4. Attacker skill
   [**purpose**] to take the ball, dribble, shoot and pass
   [**number of robots**] 1˜4
   [**algorithm**]

```
if(not keep the ball AND other Attackers do not keep the ball)
    then move to the ball
else if(keep the ball)
    if(opponents also keep the ball)
        then spin around to flip the ball
    else if(opponents is far from the ball)
        if(the shoot course is open)
            then shoot
        else if(opponent robot dose not stand between self and
                teammates)
                then pass
        else if(the distance between the starting dribbling point
                and current point is shorter than 500mm)
            then dribble the ball
        else
            then shoot
```

8 Conclusion

In this paper, we described the configurations of the RoboDragons system in detail. We described the Robot hardware first, and then the software in it. Next, we described the software system on the host computer. The main (sub)systems of the software system are the vision system, the world system and the soccer system. In the vision system, it detects the positions of the ball and the robots. They are sent to the world system. In the world system, the history data are managed to give suitable information to the operator through the GUI and the soccer system. In the soccer system, suitable actions of the robots are computed under the current strategy that is decided from the history data. We described the strategy decision method and the typical actions of the robots in our system. In the future, we will develop and make a more stable and flexible system.

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