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Patriarcas/MINHO Football Team

Patriarcas

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Abstract. *Autonomous mobile robots are ever increasing their number of different applications, even in ludic application or in sports. In the last few years, several competitions of football have been organised with lots of teams participating. This paper describes an Autonomous Mobile Robot which plays football and it was developed at the Industrial Electronics Engineering department of the University of Minho in Guimares, Portugal. Each team is free to solve on his own way all the different electronics, sensory systems, playing algorithms, etc. as far as they cope with the rules imposed by the organisation. Instead of using several different sensors increasing electronics complexity, it was decided to use only one major sensor namely a vision system with the use of a colour camera. All the image processing algorithms were developed from scratch and are hereby described. This vision system uses an innovative approach. In order to see the whole field, a convex mirror was placed on the top of the robot looking downwards with the video camera looking upwards towards the mirror. This way, the robot can see both goals, the ball and other robots, almost all the time, as well as having a top view.*

1 Introduction

A robot was built to participate in an international competition of robotic football, namely the "Festival International des Sciences et Technologies" held in France. These type of competitions are getting more and more frequent as well as more competitive as more universities are getting involved. New and innovative ideas are being raised by different teams from all over the world, not only on mechanics means but also on electronics, computer science, image processing, etc. Although this type of robotics application seems to be only ludic, some of the techniques developed can then be used in industry for real applications. In this team a group of people was gathered together from different field: electronics, computer science and mechanics in order to achieve the best possible solution. This article describes the robots as they were implemented for the previous competition and the improvements made specially for the RoboCup99 to be held in Stockholm.

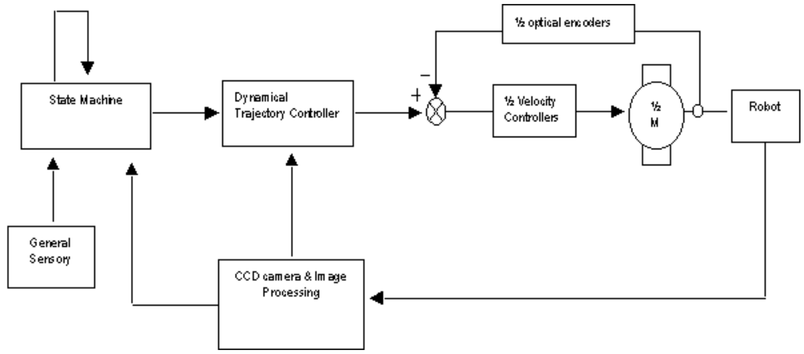

Figure 1: Figure 1: System description chart

2 Robot Description

All the robots of the team are equal. This means they have exactly the same hardware and the same software. Therefore, only one robot will be mentioned in the text.

2.1 Hardware

Presently the robot hardware architecture consists mainly in a vision system, an onboard computer and an electronic module to interface the computer with the two motors, sensors and actuators. The robot is based in a wood platform with two propelling wheels (and two support points) so the robot direction is obtained by differential control of the two DC motors. The Vision System consists of a CCD video camera, a convex mirror and an ordinary frame-grabber. The association of the convex mirror with the camera provides 360 of visibility to the robot as well as a top view of the field. The “Brain” of the system is an ordinary PC equipped with a 200 MHz MMX Pentium processor. The computer controls literally everything from image acquisition to motor speed. The two DC motors are driven by Pulse Width Modulation (PWM) generated at the computer. Since the two wheels are equipped with optical speed encoders, the computer can make an efficient speed and position control, which is very important to maintain a stable direction and to allow dead-reckoning techniques. The energy for the system comes from two 7Ah Lead-Acid batteries. One of them feeds the DC motors while the other is dedicated to the computer.

2.2 Software

The Control Software that drives the robot is organised in a 3 layered hierarchy, namely: High Level State Machine, Dynamical Direction Control and the low level Motor Speed Control. The State Machine GRAFCET based algorithm takes care of the robot and game status and provides the major directives to the behaviour of the robot. The Dynamical Direction Controller is responsible for keeping the robot in the correct and stable trajectory towards the ball, the goal area or opposite team robots. The velocity control consists of a classical Integral-Proportional algorithm.

Figure 2: Figure 2: Mirror and Camera Support (side view)

These control algorithms use input provided by some support software modules such as the Image Processing Unit or the Velocity Encoders driver and produce output to other support software such as the PWM Generator Unit. The other robot output comes from the PWM generator that control the energy provided to each motor. This modulator receives the speed requirements from the high-level control modules and drives the DC motors directly through a bi-directional Power Bridge.

2.3 Image Processing

Despite the Image Processing could be considered software, due to its importance in these robots it was decided to have a section specifically dedicated to it. This is responsible for keeping track of the ball position in the field, to locate the goal area and opposite team robots. The approach used is based on colour segmentation techniques, so the robot identifies the ball and the two goal areas using different colours on each of these entities. An acquired position in the image can be translated in a field physical position very easily thanks to the panoramic view provided by the convex mirror. Since most of the core routines were implemented in Assembly Language the robot is able of processing more than 30 frames per second.

The convex mirror used enables the robot to have a wider and better vision in every direction and from the top. The convex mirror conveys the surrounding scenery to the camera. This increased vision field enables the robot to locate the ball, as further as 8 metres away, although this value is dependent on the distance between the mirror and the camera. The 360 degrees vision helps to control the ball without losing it from sight or to detect the presence of opponent robots even at the back side. The vision from the top helps to locate the ball, even if this is behind other robots. This way, time is not wasted to search the ball. This technique enables the robot to see the ball and the goals on the same image. Next figure describes the position of the mirror and the camera.

Since the image processing detects the ball and goals by its colour, distortion caused by the mirror can be ignored. This small amount of distortion can also be seen as an advantage since when an object is closer, its size is increased by the mirror, being represented on the image with more pixels and therefore the detection becomes more reliable with higher precision.

Figure 3: Figure 3: Robot Vision

With the use of the convex mirror, the robot does not need to run all over the field, looking for the ball or the goal. Therefore, the robot moves towards its targets, saving energy and time.

The next figure shows a typical image taken from the video camera (please, ignore all the other objects on the image). It is visible that the image is slightly curved due to the shape of the mirror, but as it can be seen no algorithm is necessary to correct the image. This image is perfectly workable.

3 Game Tactics

All the four robots are equal what concerns hardware. The software of the robots is also extremely similar except for the goal keeper, which has a flag on the software, saying he is the keeper. Each robot has a "space" on the field where is will spend most of the time. That doesn't mean it can't go to other places, but means that it is his area of influence. Each robot is prepared to avoid obstacles (wall around the field and other robots) at the same time as it plays.

The robots use as sensors: Vision, Encoders and radio communication. Vision is the main sensor and is used to: *Determine the ball location* Determine the goals location *Define the field limits* Determine the robots location

The encoders are used to: *Determine the robot location on the field* Guide the robots to a target previously seen

The radio communication is used to: *Complement the vision system by messages send by other robots* Coordination in the game strategic

Each team is made of 4 robots: 1 goalkeeper, 1 defender, 1 mid field and 1 attacker. Each robot has his own area of influence. Should it need to move into another area, the robots swap positions.

The goalkeeper main task is to kick the ball as far away as possible from its goal, returning immediately to his own position which is between the goal posts. The rest of the time, it stays on the goal and its only action is to keep orientated towards the ball direction. When the ball is at a minimum distance, it defends again his goal by approaching the ball. As this robot is the one who spends most time still, it is also responsible for calibrating the encoders of the other robots.

The defender mais task is to block the opponent robots in order to complicate their life what concerns scoring a goal. His mais area of influence is the centre of the team field. Should it get hold of the ball, it starts behaving as an attacker and tries to score a goal swapping positions to other robot of his own team (attacker and mid field). In case it looses the ball and far from its traditional position it tries to come to its original position.

The mid field main task is to transport the ball from the defence into the attacking region. This robot also tries to get the ball from the opponent robots and score a goal (in case it is in a good position to do so). This robot plays and co-operates with the defender and the attacker.

The attacker robot area of influence is near the opponent goal, in order to get the best strategic position to score goals. It plays and co-operates with the mid field robot.

Every robot in the team, when sees the ball, communicate so by radio, in order to give its location as well as the ball location. By crossing all the radio information together with its own sensors information, each robot determines its internal status and takes the best decision, performing it and therefore playing football.

4 Conclusions

The idea of using a convex mirror proved to be very successful as it gives several advantages like 360 degrees vision, vision from the top, increased field of view, more concentration of pixels in the objects near (allowing higher precision in the calculations), and all this is achieved with only one camera, reducing though weight, computational requirements and saving energy for other tasks. The image processing software is written in Assembly language in order to increase processing speed. This proved to be a big advantage since around about 50 frames per second were obtained. The rest of the program is written in C language. Although the tactics of the game seem to be easy and simple, the robots play well and do their job. Smooth movements, obstacle avoidance, were also achieved and consist of routines which behave by them selves and do not use much computational resources.

5 References

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