GEAR 2009 Team Description Paper

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Abstract. Developed with limited resources and only by undergraduate students, the GEAR 2009 Small-Size team hardware is very robust and presents full soccer capabilities, such as fast omnidirectional movements, kicking, passing and dribbling. Besides that, our software systems brought new techniques that proved to be extremely successful, mainly for computer vision and distributed systems integration. This paper brings an outline of both, hardware and software systems, in order to show our project's main features.
Keywords: Robot soccer, robotics hardware, computer vision, artificial intelligence.

1 Introduction

Founded in 2003, GEAR ("Advanced Robotics Study Group", in Portuguese) is a group of around 30 undergraduate students from the University of São Paulo whose objective is to study, project and implement, by themselves, everything related to the development of a robot.

Currently, we create F-180 robots and our best result is a 2^{nd} place in the 2008 RoboCup Latin America Open, held in Salvador, Brazil, playing with our second generation team.

Our third generation robot and the new versions of the software systems bring a whole new set of improvements as described in this paper.

2 System Summary

The team is controled by GEAR Backbone, our central software, that receives from our stereo vision system the game objects positions, which are read by the AI in order to choose an appropriate strategy to each player. These strategies are sent back to GEAR Backbone and then passed via radio to the robots, as show on Fig. 1:

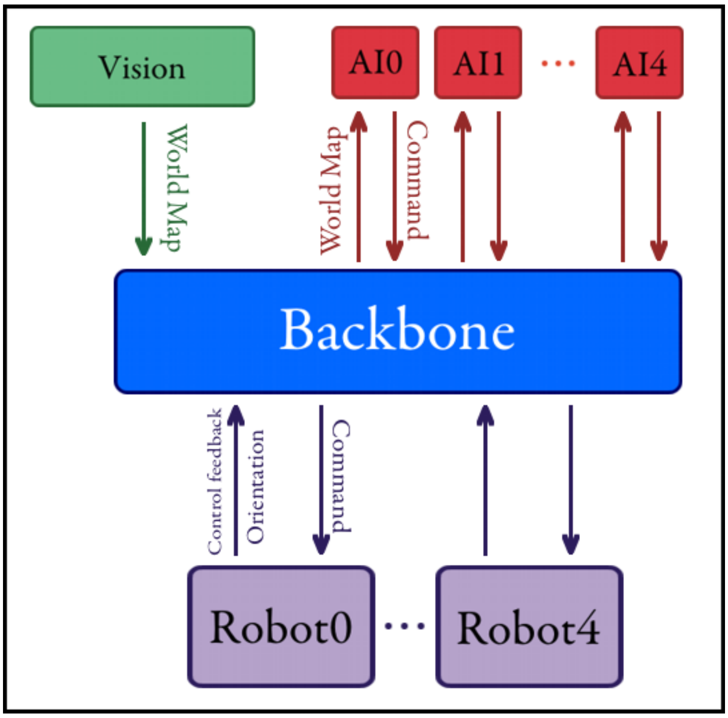

Fig. 1. GEAR System architecture

We have six identical robots whose diameter and height are, respectivly, 179mm and 143mm. The third generation robots are able to cover 20% of the ball to dribble using a rubber bar; to identify when the ball is in their possession thanks to an electronic sensor on the kicking device; and to move at around 2 m/s in all directions thanks to our 4 electrical motors.

3 Hardware

The hardware team had the challenge of creating a low profile multi-function circuit capable of controlling a F-180 soccer robot: recieving telecomand data from the main processing system, implementing communication protocol and error control, controlling a set of electrical motors and providing game functionalities such as kicking and dribbling.

The technology involved in the creation process divided the team in 3 subgroups: digital, analog and power electronics.

There are currently two generation of robots used by hardware team, it is respectively second and third generation of GEAR F-180 robots. First generation robots was base to second, as second is base to third, thou first generation is already deprecated and abandoned. The second generation is a solid development complete generation of robots already used at an international tournament. The third is the second generation expanded in functionalities.

The second generation architecture's idea was to create a central digital unit capable of receiving and processing the command packages and setting the robot electric motors configuration as well as controlling functionalities offered by analog and power circuits. By first analysis the following capabilities should be implemented by hardware team:

- Capability of receiving wireless communication
- Capability to interpret a communication protocol
- Control over 3 electrical motors via driver CIs for moving
- Control over 1 electrical motors via driver CI for ball possession
- Circuit capable of charging high voltage capacitors
- Circuit capable of firing a solenoid
- Capability of in-circuit kernel reprogram
- Battery status awareness

All this capabilities include implicitly circuit robustness, a hard to fine quality when integrating digital, analog and power electronics. The circuit should be low profile, as its result should be easily reproducible at low cost.

Some research was done by sub-groups for hardware shelf products to fulfill robot requirements, in all cases integrated CIs and complementary analog circuits were necessary. There were decided some base electronics and a circuit layout as depicted in Fig. 2.

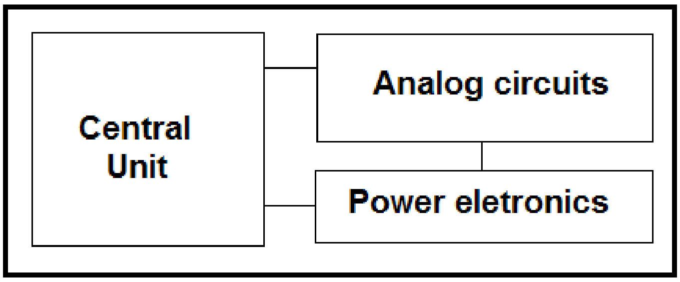

Fig. 2. Block diagram of circuit layout

Central Unit comprehendeds:

- A PIC IC containing the hardware kernel responsible for processing communication protocol and setting hardware configuration;
- A Laipac IC responsible for wireless communication;
- An USB bridge for in-circuit kernel re-programming;
- A battery status awareness circuit.

Analog circuits comprehended:

- A DC/DC circuit for high voltage capacitors source;
- An analog circuit to control DC/DC operation and its battery consumption;
- A circuit for motor drivers.

Power electronics comprehendeds:

- Output of DC/DC circuit and capacitors charge;
- Shooting circuit for solenoid.

The Central Unit commands PWM signals on analog circuit drivers and the shoot of solenoid. Analog circuit DC/DC output was input source of power electronics block. It was necessary line filters at Central Unit block to improve robustness and a protection for electromagnetic discharges from the power electronics block.

All blocks were implemented in a unique printed double layer circuit. Outcome board was able to control robot action with a 16V battery power supply. Robot battery autonomy hardly depends on its use, at maximum current use battery lasts roughtfully 30 minutes going for more than an hour at normal game usage.

Third generation robots are an expanded version of second generation. All learned experience and faced problems are treated on this new robot. Since second generation, robot was only able to receive commands from GEAR Backbone. In this new generation, the robot can send back telemetry and gyroscopy data to the Central System, allowing orientation calculus and better movement control.

The third generation brings:

- Capability of sending telemetry back to a central computer
- Wireless protocol robustness to handle multiple communication entities
- Electric motors encoders to feed data back
- A ball possession sensor
- A rotation sensitive circuit to feed data back

Besides this new functionalities, almost all former circuits were revised. Improvements consisted of better conversion system at DC/DC, the use of two PICs on Central Unit and better line filters.

The circuit layout is the same from the second generation, but some items were replaced. The major change was the communication IC that changed from Laipac to a Xbee protocol IC. The data feedback rate is equal to the World Map creation one.

This data dynamically models robot operation on our Central System and makes it able to improve the control of its movement. Another improvement was the add of a new electrical motor, allowing omnidirectional movements. Allied with a rotation sensitive circuit and motor encoders, each robot can report many important characteristics of its operation to the Central System.

The ball possession sensor was included in the circuit as a problem solving measure. Hence it's hard to tell exactly by images when the robot has ball possession, this sensor gives a deterministic signal of the possession makes robot aware of its condition.

Since circuit central unit processing power was divided between two microcontrollers, there was a need to implement a communication protocol between them. One controller is responsible for communication and feedback data while the other is responsible for maintaining robot operation. The communication between both occurs by SPI protocol.

4 Vision System

The vision system is resposible for locating and recognizing the game objects (ball and robots) and creating the world map, which is sent to the AI system, allowing them to plan how the robots must act.

4.1 Architecture

The system is divided in 3 sub-systems: Video Handler, Object Recognizer and Communication Handler, respectivly responsible for capturing and processing the video, finding and recognizing game objects and communicating to GEAR Backbone, as show on Fig. 3.

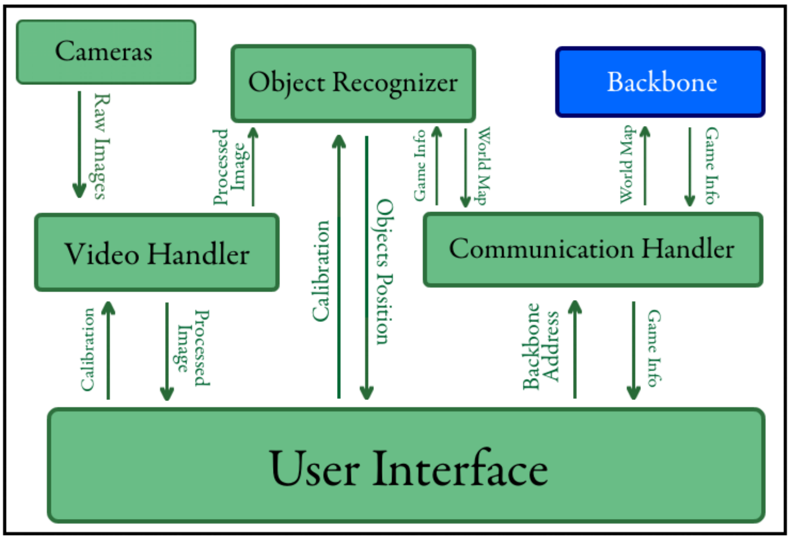

Fig. 3. GEAR Vision architecture

4.2 Video Handler

In order to capture the game events, our stereo capture system consists of two overhead FireWire cameras, which video is captured at 1024x768-30fps using the DC1394 library.

The captured frames are joined, creating a single image of the field that is processed using a set of energy and morpholocial filters, resulting in a cartoon-like image.

4.3 Objects Recognizer

This module receives the already processed image and searches for pixels that match the desired colors. When those are found, a neighborhood analysis is made, determining if it's a game object or just noise.

The reconized objects location is set to the World Map that will be send to the Communication Handler.

4.4 Communication Handler

The Communication Handler is a thread that interfaces with GEAR Backbone, receiving game information and sending the position of the recognized objects.

4.5 User Interface

The new version of the User Interface is still under development. However, it will be built using Qt 4 and will allow users to set system variables and view the position of the recognized objects.

It's previous version, shown on Fig. 4, was able to perfom these actions, but it couldn't be integrated to Vision' and Backbone's new versions.

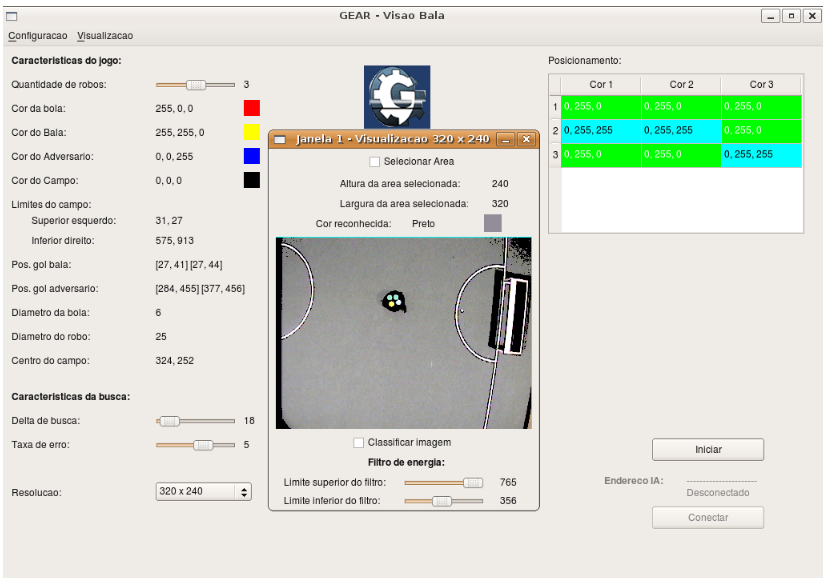

Fig. 4. Old Vision User Interface

5 AI System

The goal of the AI system is to receive data from the vision system and, based on this data, drive our robots to the next position. For each batch of data received from the vision, the AI makes a new decision and sends a message to each robot, the messages contain the robots' new actions.

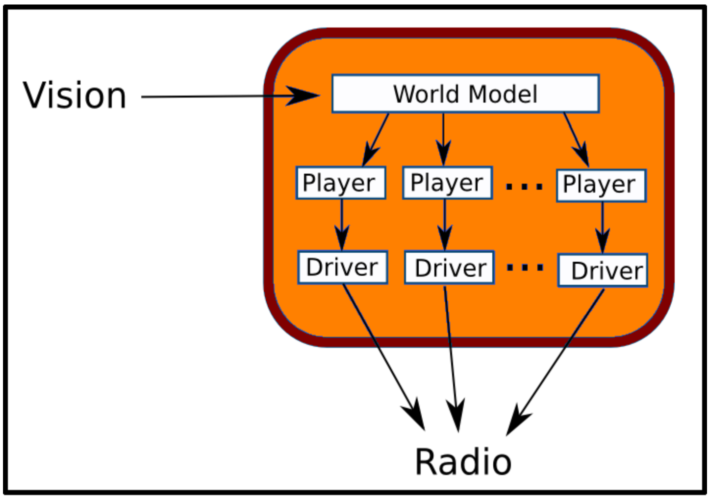

Fig. 5. GEAR AI architecture

5.1 World Model

Data received from Backbone consists in the actual position and angle of all robots in the field, and position of the ball. This data is stored in a World Model that is available for the threads that represent each robot.

5.2 Coach

The Coach is responsible for starting the players and sending them messages that can change their actual strategies. The game status, like offsets, throw-ins, corner kicks and game score, are perceived by the Coach, that can change players' strategies based on this information.

5.3 Player

Each Player is a thread, an independent agent that can fetch data from the World Model and make its own decision about what to do. The Player have the following main behaviors:

- Make pass: the player is trying to perform a ball pass;
- Wait pass: the player is going to the best position to receive a ball pass;
- Shoot: the player is trying to kick to goal;
- Defend: the player goes to the best defensive position;
- Goal defend: this is the exclusive behavior of the goalie.

In a match, a given robot has one of these behaviors during a certain period of time. This behavior is chosen using a motivation function, which can use a set of variables to choose the most favorable behavior.

All the cited behaviors may use the potential fields method to perform navigation. Potential fields method is also used in the motivation function to select the player's behavior.

5.4 Driver

After the Player have made its decision, it sends a message to the driver. The Driver is responsible for making the robot perform the action correctly. The Driver uses a self-tunning method that gives the robot an ability to adapt to a new field, a mechanical problem or other problems related to the velocity and acceleration of the robot.

6 Members

Here is a complete list of members of our team:

6.1 Hardware

Andre Corsetti, André L. B. de Miranda, Marcelo Tomasini, Carlos E. de Almeida, Renê de S. Pinto, Lukas A. Reis, Pedro H. N. dos Santos, Vitor S. Montes and Vinicius Rosseti;

6.2 Mechanics

Wladmir R. A. Junior, Elias B. Gutierre and Gabriel R. Bombini;

6.3 Vision

Rafael G. Lang, Jose A. Stuchi, Emerson F. dos Santos, Heitor B. Florido, Mariana Antoniazzi and Caio M. Yassoiama;

6.4 Artificial Intelligence

Gustavo C. Martins, Augusto C. M. Gil, Danilo V. Vargas, Thiago C. Fernandes, Leandro C. Rondon, Thales B. Pasqual, Ivan F. R. da S. Filgueiras, Eduardo R. Moreira, Matheus B. Teixeira, Airton G. Finoti and Eduardo Fraccaroli;

6.5 Administration

Patricia M. B. Kikuthi, Luciano J. Loman, Bruno S. Crippa and Diogo F. S. Ramos.

7 References

1. Zickler, S., Vail, D., Levi, G., Wasserman, P., Bruce, J., Licitra, M., and Veloso, M.: "CMDragons 2008 Team Description", Carnegie Mellon University, 2008
2. Kriengwattanakul, A. et al.: "PLASMA-Z 2008 Team Description Paper", Chulalongkorn University, 2008
3. Otsu N., "A Threshold Selection Method from Gray-level Histograms", IEEE Transactions on Systems, Man and Cybernetics, v. SMC 9, no 1, pp.62-66, 1979.
4. Koren, Y.: "Potential Field Methods and Their Inherent Limitations for Mobile Robot Navigation"
5. Serra, J.:"Image Analysis and Mathematical Morphology", 1982