TDP - Furgbol-PV

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***Abstract*— In this paper, we describe the new Citizen's micro-robots and the platform used in RoboCup's Mixed Reality category. Later, we present our mixed reality researches using these robots. These researches focus on the study of Mixed Reality applications for this platform. Moreover, we show our contributions to the development of this Mixed Reality platform: the development of an automated calibration system for vision module.**

I. Introduction

Nowadays, different robot plataforms are used for real problems as, for example, rescue vehicle, exploration and inspection vehicles. Among these diferent categories of robots there are the little mobile one, which can be used for simulations or even for entertainment. Such type comes to attend a market supplied mainly by simulation. In the Robocup [1] this kind of robots are used in a new category proposed by Citizen, denominated Physical Visualization, and latter called Mixed Reality, that enables the utilization of these robots in a virtual environment experiences.

The aim of Mixed Reality Contest is to motivate the students to plan and evolve complex systems that mix real with virtual elements, which introduces a concept of Mixed Reality (MR) [2].

The MR can be described as an spectrum that in one side is the Common Reality and in the other is the Virtual Reality [3]. In the middle of this spectrum there is the Augmented Reality (AR) and the Augmented Virtuality (AV). AR is based in the real world incremented with virtual information, while AV is based on the virtual world incremented with real information.

The Mixed Reality Robocup category is carry out, currently, by twelve research groups around the world (our team is one of them). These groups are responsible by the development of the competition platform, beyond its own contributions. In our group, we contributed with the following aspects:

- improvement of the micro-robot platform by allowing it to become a standard test bed for multi-agent/multi-robots research;
- development of scenarios for micro-robots in educational tasks;
- use the micro-robots in research in robotics and multi-robots systems;
- apply the contributions of the research using micro-robots in other areas;

More precisely, our group have collaborated with the proposal of two different contest: PAC-Man and Battle City MR games. Besides, we developed an automatic calibration system [1] for the camera module, which will be incorporated in this platform.

In this article, we present an overview of our studies and results related to the contributions above, focusing on the game proposals and the automatic calibration system. This paper is organized as follows. In the next section, we present the platform structure and the micro-robots. The section III presents the current researches and game projects developed using Citizen micro-robots. The section IV is dedicated to a detailed explanation about our automatic calibration system. Section V shows our results. Finally, section VI summarizes and concludes the present paper.

II. Micro-robots and Mixed Reality Platform

Our group is one of 12 institutions around the world chosen to receive from Citizen the development kits to the new category of Mixed Reality of the RoboCup. These kits contain micro-robots and infra-red transmitters.

This new category, created in 2007, has as goal the development of new technologies based in mixed reality. The difference of this category in relation to the others, besides the robot size, is the use of a screen to project the environment of virtual reality. This way, each robot must interact with virtual and real elements.

a) The micro-robots: used has two wheels, measuring about 1.5x1.5 cm of base and 2 cm of height and are powered by a battery clock, see figure 1.

b) The Platform: is a hardware and software structure that is capable of immersing the micro-robot in a Mixed Reality environment.

The hardware architecture is composed of: a LCD screen; a computer (server); a camera connected to the server; and infra-red transmitters. Moreover, each group

[1] Source available in http:\\www.ee.furg.br/~furgbol

Fig. 1. Citizen's micro-robots

that wish to use the platform must have another computer (client) that connects with the server.

The server projects the virtual environment on the LCD screen. The robots are placed on the LCD (prepared horizontally) and a camera positioned above the screen captures images and transmits to the server. This must analyze the images, recognize the positions of each robot, and after, transmit that information to the client. Clients, in turn, are responsible for elaborating actions (strategies) to be taken by the robots and send them to the server. This, connected to the infrared transmitters, sends the information received to the robots.

Figure 2 shows schematically the platform structure, demonstrating one of the activities of the MR category, which consists of a soccer competition. In this category, the field elements (goals, ball, and field markings) are virtual and projected on the LCD screen, while the players are represented by the robots that move on the LCD.

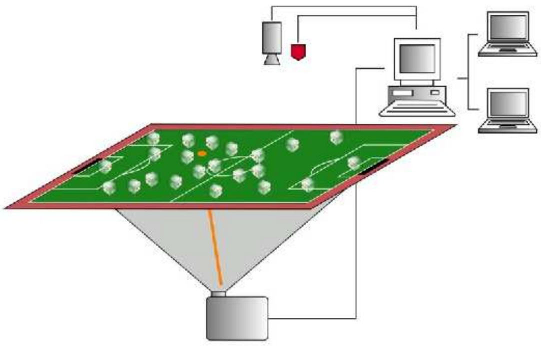

Fig. 2. Mixed Reality Platform

The software architecture is composed by server and client. The server system includes the image processing, computational vision, assembly of the virtual environment, physics modeling of the virtual elements and the communication by infra-red transmitters. The client system consists of the robots decision-making software. In addition, the systems have modules to communicate with each other over the network.

The main contribution of the MR category is not the construction of the agents, but the development and optimization of the environment. The MR proposes competitions based on improving the robot project (aggregation of new sensors, improvements in the firmware, etc.) and proposing new environments using the described platform. In this sense, the purpose is to build a generic platform for the development of Multi-agent systems and from this make it possible the test and verification of various strategies and techniques in environments under multi-agent restrictions.

This mixed reality structure offers the following advantages:

- Construction of virtual environments that would be difficult to build using real elements;
- Easy Modification of the virtual objects characteristics;
- Reduction in the cost of project due to emulation of sensors and actuators, which can be simulated virtually.

III. Current Research in Mixed Reality - FURGBOL-PV Game Proposals

Our group has developed several researches in mixed reality, with the main activities:

- the formation of a soccer team to compete in the RoboCup;
- the creation of demo applications, associated with games, to participate in the RoboCup;
- the development of a automatic calibration system to collaborate with the mixed reality platform.

A. *RoboCup Soccer*

In order to compete in RoboCup, we have been developing soccer strategies and demo applications in order to leverage usage of Citizen's micro-robots and their standard setup. The figure 3 shows the micro-robots in soccer game.

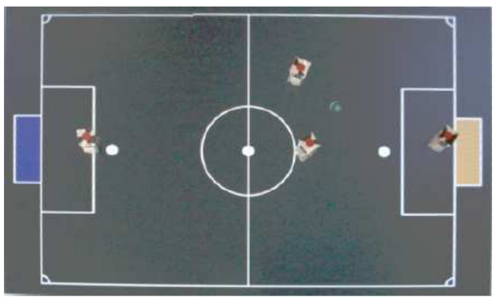

Fig. 3. Citizen's micro-robots in a soccer game

The development of our soccer team is largely influenced by our successful strategies in Small Size and 2D Simulation leagues. Our current strategy involves the exchange of roles between players. In response to the game dynamics, the goalkeeper can become the attacker, and the attacker becomes the goalkeeper. The high level strategy is based on a state machine, whose states are related to players and ball positions. The transitions in this state machine are determined by the game dynamic.

Our algorithm divides the field in four vertical regions. States are composed of the region the ball is in and who has the possession of the ball. In this way, it is possible to recognize when to take actions such as evading an offensive attack or guiding the ball towards the opponent's goal. Roles between players are exchangeable and each may adopt a defensive or attacking strategy according to their position on the field and in relation to the ball and adversaries.

For example, a player may acquire the role of the goalkeeper whenever the adversary has the ball and the player is close enough to its own goal. The goalkeeper has its own algorithm to defend the goal, according the figure 4. The key idea is to keep the goalkeeper between the ball and the goal's central line, since kicks are always made in a straight way (i.e. no curves).

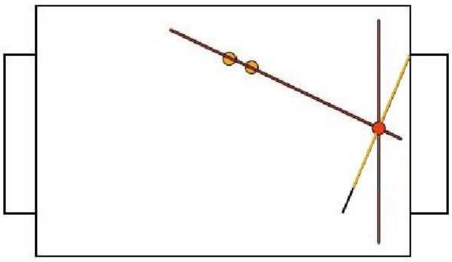

Fig. 4. Goalkeeper strategy

Furthermore, we have developed a library that implement global motion functions considering the global (inertial) reference frame instead of the frame attached to the robot.

B. RoboCup Demo Applications - Mixed Reality Games

In order to extend the use of Mixed Reality standard setup, we have been developing demo applications in the form of classic games that are playable in mixed reality. Two games were adapted to this new platform: the classics Pac-Man and BattleCity.

1) The Pac-Man: is the well-known game where the player controls a character who must "eat" all the food in a maze while escaping from ghosts which may kill him. For this game, a micro-robot is used in place of the player's character while all other elements are simulated in the underlying video monitor. Since the maze severely constrains the movements of the robot, a central issue becomes to convincingly allow for the interaction of the robot with simulated aspects of the environment without damaging the gaming experience. The figure 5 shows this game.

2) In BattleCity: players control tanks in a maze and must destroy all other players by shooting bullets. The

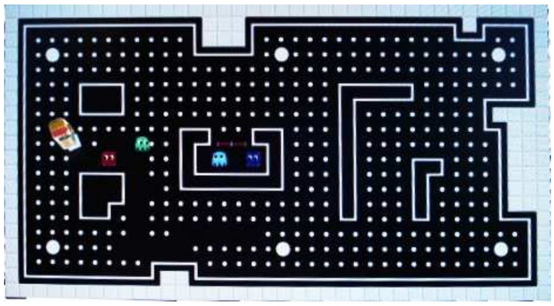

Fig. 5. The Pac-Man

maze can be destroyed by the bullets and have dynamic parts (such as moving bridges or gates). For this game, each player controls one micro-robot which plays the role of one tank. All other elements are simulated and rendered in the underlying video monitor. This is a step further compared to Pac-Man, since now not only the maze may constrain movements but it can also be dynamic and modifiable by the players' actions. Future implementations of this game will allow for real blocks to be put dynamically over the video monitor by the players, forcing the robots to interact with both real and virtual obstacles. The figure 6 shows this game.

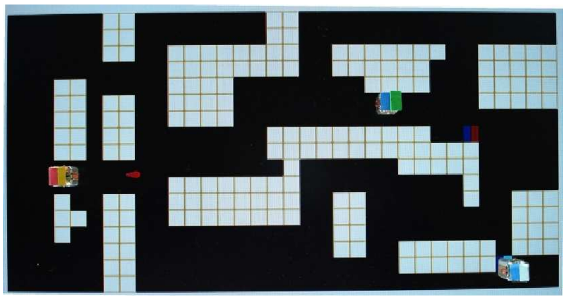

Fig. 6. The BattleCity

These demo applications shows briefly the utility of Mixed Reality. The easy construction of virtual environments, like the maze, that would be difficult to build using real elements. The easy modification of the virtual objects that can disappear, like ghosts in Pac-Man and walls in Battle City. And the emulation of bullets in Battle City.

These games are also environments of study of traditional computer problems, that must be treated in real time:

- Computer Vision - Image segmentation, color classification;
- Artificial Intelligence - making decisions in real time.

In order to provide the information not only of the robots but of all the game scenario, the global vision was adopted. Through a set of image processing techniques, the system performs a set of stages, such as radial distortion correction and segmentation based either on the HSV or normalized RGB color space analysis.

The color classification, based on previous acquired frames from the empty field of play, each new frame is subtracted of the empty ones. This technique reveals the areas of the new image substantially different of the old ones in view of diminish the amount information to be processed. After the image subtraction only the pixels considered relevant to the process undergoes color classification. A system based mainly on normalized RGB is used. See [4] for more details.

The figure 7 shows the segmented objects and colors classified of the figure 6.

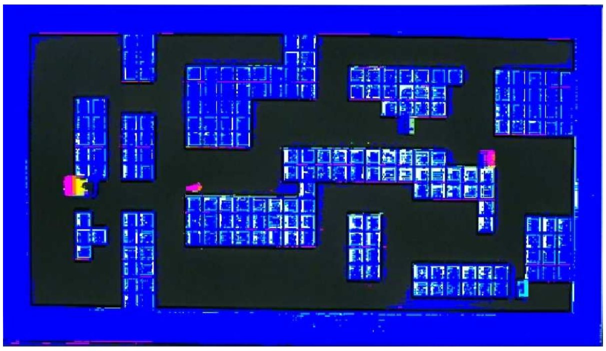

Fig. 7. BattleCity - classified colors

For these applications, the next development step is to allow for a large number of micro-robots to play the game simultaneously. For Pac-Man, other robots would take place as ghosts and for Battle City, as other tanks or even dynamic obstacles. This will provide full benchmark scenarios for Multi-Agent and Multi-Robot coordination and competition.

C. Platform Development

In addition to RoboCup, our team has been collaborating with creation of the next-generation platform for Citizen's micro-robots. In particular, we have been dealing with the problem of automatic camera calibration.

The current process of camera calibration is a long and error-prone process as it requires lots of interaction with the user. To automate this process will allow a faster, easier and more reliable calibration, avoiding minor errors from manual calibration and objects misdetection.

The next section is dedicated to a detailed explanation about our automatic calibration system.

IV. An automatic camera calibration

The automating process basically sums up to two stages: (i) correcting distortions caused by camera placement; (ii) performing color recognition. In its turn, the pattern recognition stage is a step of difficult automation once that needs human interaction anyway, leading us to not automate it entirely.

The distortion correction stage consists of displaying a standard pattern (more specifically a grid) on the screen being captured by the camera and matching it with a similar pattern displayed on the monitor. Once this standard pattern is previously known, it is possible to discover what should be displayed based on what is being captured by the camera. Our correction algorithm recognizes the grid nodes through color differentiation, obtaining a model of screen's displayed grid and outputting correction parameters for the camera.

For color recognition, the system scans all images in search of samples of a specific color (red) in accordance with some distinguishing features of this color. These samples are gathered into blobs and displayed on the monitor, grooming the system to automatically calibrate through a learning of the color variation along the image.

Finally, the pattern recognition is related to scout image looking for the unique pattern that identifies each robot. Our algorithm detects the central color in each pattern and then identifies its surrounding design. However, the user must specify which pattern corresponds to each ID manually, mapping the robots before the main system running.

A. Correcting Distortions

This phase consists basically of matching the intersections of the grid captured by the camera with the grid displayed on the monitor, see the figure 8. The grid captured by the camera is a 5x5 grid with the colors blue and green, and the grid on the monitor has 36 nodes that should match with the first grid.

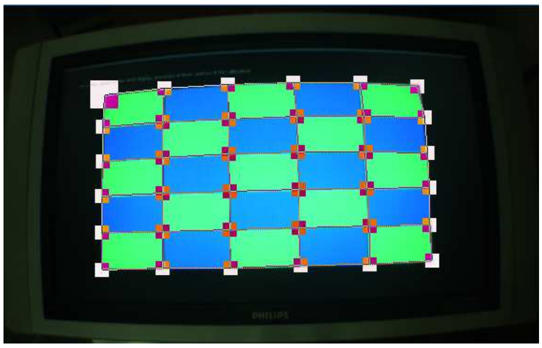

Fig. 8. Points automatically recognized in the grid

Our system analyses the image searching for this intersection points. To do so, we scan the image with windows of 16x16 pixels, if a window presents a expected pattern then this place is marked to receive a node.

To differ the patterns we divide each window in smaller windows of 8x8, then we analyze the colors inside each smaller window. The patterns can be:

- upper left and lower right smaller windows of a color and upper right and lower left smaller windows of the other color.
- two neighbor smaller windows (like upper left and upper right) of different colors and the other two smaller windows of another color, usually black.
- only one smaller window of blue or green and another color, usually black.

When all 36 points are found on the image, we just sort then and match then with the respective point in the grid.

B. Color Recognition

The main problem here is to find on the image every red color. This color is used to identify the robots that are placed on the LCD screen. The server creates a map with the variations of the red color on different places of the image.

This process was made by positioning a red marker on the field and then drawing squares on the image where a red color appears. This way the server could identify that variation of red. The main problem of this method is that if the user, by accident, marked a square in a place that had no red the server would analyze a wrong red variation.

Our system analyses the image before the user can start drawing squares, searching for every red pixel. Then the system should send these red variations to the server and show the user the level of the calibration achieved, by highlighting the red pixels. After this automatic calibration the user is able to draw squares to improve the calibration or just finish the calibration.

V. Results

FURGBOL has demonstrated good results in the last years through competitions in robotic soccer [5] [6] [7] [8].

An initial version of our high-level strategy for the soccer team and our applications demo ranked fifth in RoboCup Atlanta 2007 and second in RoboCup Brazil 2007.

Our automatic calibration system has shown good results in tests, and should be used in the RoboCup 2008. The system calibration was intensively tested in several conditions of lighting, and of radial distortions. It proved to be tolerant to heterogeneous lighting, and lack of lighting. Rarely has the system positioned incorrectly some points of the calibration grid. But the sorting of points enabled the right connection of them points. After a supervised correction enabled the best positioning.

VI. Conclusions

After participating in the RoboCup World Championship, we could realize how promising is the Citizen's platform. At our University the micro-robots and the concept of mixed reality are being used for research and educational purposes.

We have proposed two MR games using the PV platform. These games mix classical PAC-MAN and Battle City agents with real PV-micro robots. The platform uses computer vision strategies, allowing a virtual scenario with real and simulated robots to play.

Besides, our group has been dealing and proposing solutions for general problems such as global locomotion library, camera calibration, image filtering, color space transformations, multi-robots and multi-agent system.

As future works we intend to achieve a more extensive set of test and validations of our approaches. A 3D Citizen micro-robot model is also developed by our group. This virtual 3D structure will be integrated with a 3D virtual scenario used in a Quake and UT (Unreal Tournament) game platform. Moreover, it is intended to implement a set of applications and games merging real micro-robots with simulated 3D environments.

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