

# CITIZEN Eco-Be! and the RoboCup Physical Visualization League

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**Abstract**— We describe a new standard research and education platform integrating cutting-edge and low cost watch technology into a miniature multi-robot system which mixes reality and simulation. We also introduce the concepts of a new competition, so-called "Physical Visualization", to be part of RoboCup – the international robot soccer competition – from 2007 on.

## I. INTRODUCTION

In robotics research, lots of benefits can be achieved by using a standardized platform that allows for an easy comparison of results and concepts. However, there is a lack of a standard platform that provides the flexibility of simulations in real robots at a reasonable price. To address this, we introduce a new setup based on a project sponsored by CITIZEN CO. It makes possible a huge variety of different usages for a large number of mini-robots in an augmented reality (AR) environment at quite inexpensive costs. The core of the project is the CITIZEN Eco-Be! mini-robot [1], [2]. It is built using cutting edge technology in miniature robotics using high quality and low-cost CITIZEN watch technology.

Up to date a few developments have been made on very small sized robots, being ALICE one of the most prominent names (see [3] for a survey). Although the Eco-Be! itself might look pretty much like other micro-robots, our proposed framework (see section IV) presents unique features that make it interesting for a variety of applications hardly possible otherwise.

Physical Visualization (PV for short) is a new RoboCup [4] sub-league of the Soccer Simulation League that will cover a broad range of fields in a variety of different competitions using standard hardware and software platforms<sup>1</sup>. This RoboCup sub-league is based on a miniature multi-robot system which mixes reality and simulation through an Augmented Reality (AR) environment (see [5] for the original league proposal). This new project has a two-folded focus: research and education.

Our main goals are:

- to gradually improve the platform so that it could become a standard for multi-agent research and education;

- to explore possible real world applications based on the mini-robots.

For 2007 a total of 300 robots will be produced, and 20 teams will be selected for receiving 15 robots each.

## II. CURRENT OBSTACLES TO MULTI-AGENT ROBOTICS

There are many challenges faced by roboticists, among which quite a lot are not necessarily related to the research discipline itself. Here we highlight two of these:

### A. Cost

Generally speaking, doing research on robotics is an expensive task. Even in the most inexpensive real-robot experiments, it is a common sense that one would expect to spend several thousands of dollars in order to have a multi-agent setup. For the main reasons, one could surely account for the unavailability of adequate commercial platforms, thus bringing the need for custom brew robots. In RoboCup the strong competition forces teams to challenge themselves to come up with new design ideas which quite often are translated into more complex and expensive hardware. This last factor also implies that a wider spectrum of fields needs to be covered for the complete design of the machines, including technical issues which are not always related to the research focus originally in mind. Such difficulties may seem inherent to the research track of some institutions, but they also prevent those who do not have the man-hour and the money for the journey.

### B. Standardization

Another common problem in robotics which is frequently overlooked is the lack of a standard platform in which one could easily compare results of different methodologies. In RoboCup, the two-dimensional environment of simulation league has already proven for years the advantage of having such standardization: hundreds of papers often show comparative results using the standard environment and playing against a provided adversary (usually the code of a good team of the former years). Also, the RoboCup four-legged league (a.k.a. "AIBO" league) shares some of these advantages as, for instance, the champion teams usually release their source code

<sup>1</sup>See <http://er04.ams.eng.osaka-u.ac.jp/> for more information.

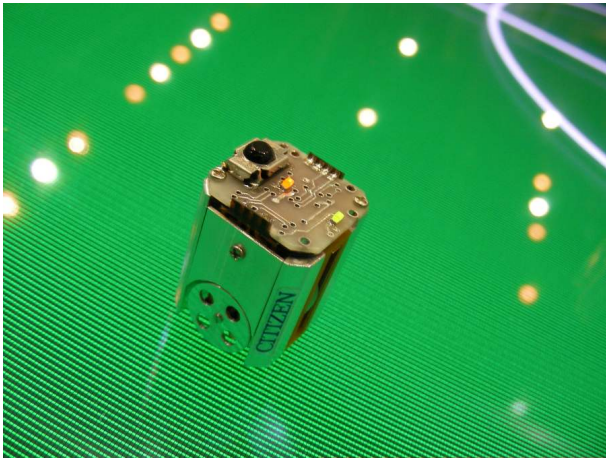


Fig. 1. The current version of the Eco-Be! robot. A newer version of the robot is under development, which should feature rechargeable batteries and improvements in speed and controllability.

for the others to build on in the coming year, thus speeding up the progress and avoiding “re-inventing the wheel” for newcomer teams.

### III. THE ECO-BE!

CITIZEN CO., is a renowned company, especially in regards to miniature devices. Currently, the company is committed to the complex task of developing a miniature-yet-affordable robotics platform. This comes in opposition to the mainstream in robotics, which generally points towards costly solutions. Instead, CITIZEN CO. focused on versatility and affordability, taking advantage of their well-established watch technology for the development of inexpensive miniature robots.

The Eco-Be! is a miniature robot being developed by CITIZEN CO. in collaboration with RoboCup – see figure 1. The Eco-Be! uses cutting-edge and low cost watch technology, enabling the notable degree of miniaturization at reasonably low cost. This allows the employment of large number of robots in a rather reduced space with a very low budget and amazing portability. The robots are to be constantly upgraded and improved, being developed and produced for the PV competitions, according to the request of participants and CITIZEN’s viabilities.

#### A. The current configuration

The current Eco-Be! was proposed as a starting point, to be followed by numerous upgrades in the long term. Therefore the current robot has a rather simple hardware configuration.

The robot is composed of the following main features (see corresponding numbers in the exploded view of figure 2):

- 1) The motor – Customized from a wristwatch motor unit (see subsection III-B).
- 2) The batteries – Current configuration uses two watch CR1612 button type batteries in serial configuration. This gives a total of 6V output. The batteries last enough for four hours stand-by or one hour of continuous usage.

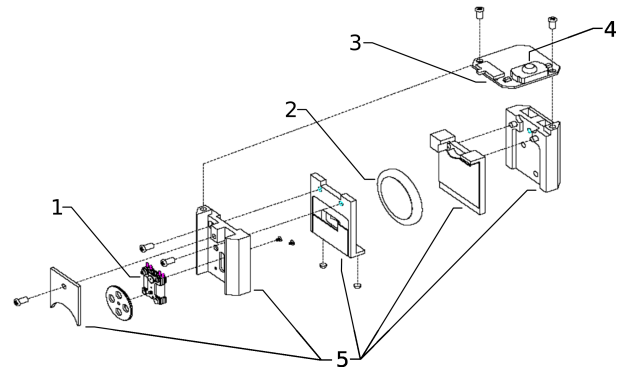


Fig. 2. Exploded view showing Eco-Be! main parts

- 3) Control board – A PIC controller (PIC18LF1220) is located on a small control board on the top of the robot. The controller can be easily re-programmed through the serial port of a PC.
- 4) IR sensor – An IR sensor is used in order to listen for commands to the robot. The sensor operates at the 40kHz bandwidth (same of most home-appliance remote controls).
- 5) Body – The resistant durable body of the robot is milled in aluminum using CITIZEN’s high precision CNC machines.

#### B. A very special motor for a very special robot

One of the main features without which the Eco-Be! would be hardly possible is its motors. The Eco-Be! uses two wristwatch motors to drive its differential wheels. See figure 3. But these motors are not simply of-the-shelf wristwatch motors. CITIZEN customized some of their production line step motor units to attend the requirements of the small robot.

The motor unit has been developed using CITIZEN:s proprietary technology, achieving thinness, high-reliability and low-power consumption. The utilization of high-speed rotation and gear reduction made it possible to achieve high torque performances. Table I shows the motor main features.

#### C. Expected upgrades for 2007

By the end of this year the first RoboCup release of Eco-Be! prototypes is scheduled to be ready for deployment. This first RoboCup version will include more sophisticated control over the differential wheels through the IR interface, and will use rechargeable batteries in order to assure more flexibility, longevity and considerable increase in the performance of the motors. The new robot is expected to show considerable improvements in the fine-grained controlling of trajectories and velocities.

### IV. THE AR ENVIRONMENT

The figure 4 illustrates an overall view of the PV default system. This setup was highly inspired by [6]. The robots follow commands given by a central server through an IR beam. The actual position and orientation is fed back to a

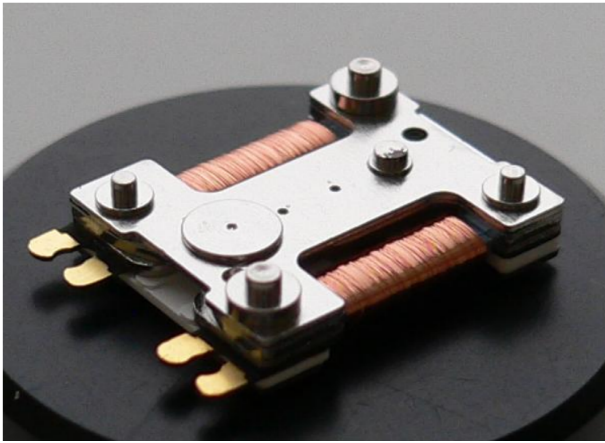


Fig. 3. Customized wristwatch motor provides necessary torque for micro-robotic applications.

TABLE I  
TECHNICAL DETAILS FOR THE CUSTOM STEP MOTORS USED IN THE ROBOT.

|                                   |                      |
|-----------------------------------|----------------------|
| Size W×D×H (mm)                   | 7.0 × 8.5 × 1.9      |
| Configuration                     | 2 coils × 1 rotor    |
| Gear ratio                        | 1:240                |
| Torque (gf·cm at 2.8V)            | between 2.0 and 4.0  |
| Power consumption at 200 rps (mA) | between 4 and 12     |
| Rotation (rpm)                    | 12,000               |
| Direction                         | standard and reverse |

server by a camera located at a high position. Up to this point this setup resembles very much that of [7]. The most noticeable difference in our approach is that a widescreen display is installed horizontally in the place of the field. The game or application environment, its artifacts and its features are displayed and/or enhanced by using the display. Depending on the game and on the limitations of the robots, real objects can also be incorporated, such as balls or obstacles.

The software architecture is borrowed from the current RoboCup three-dimensional Soccer Simulation League, thus ensuring the agents would be individually programmed as isolated agents. See the diagram of figure 5 for details. Such setup brings huge flexibility for the simulation of sensors and actuators not yet implemented in the real robots. This means the mixture of reality and simulation allows for the use of robots years ahead in design despite their current limitations. At the same time this AR setup may guide the development of new devices to be equipped in robots during the years, gradually migrating towards fully stand-alone robotic agents – which could still be optimized by AR (there is always room for improvement).

Among the main advantages of using this AR environment, one could mention:

- Great flexibility in the design of the task due to the control of the parameters of virtual objects/features (e.g.

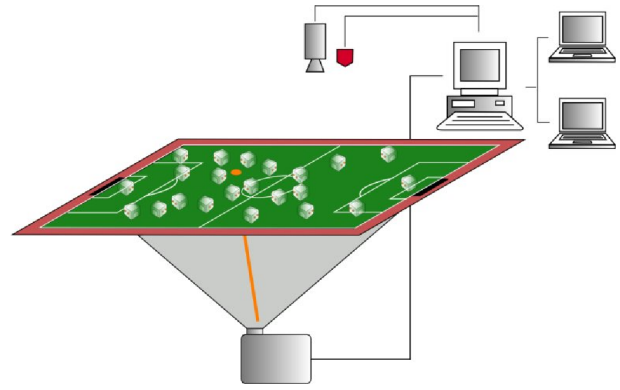


Fig. 4. Overview of the AR setup. A flat TV screen is placed horizontally as the field, allowing the projection of many visual aids. The robots are tracked by a camera and controlled through IR signals sent from the top.

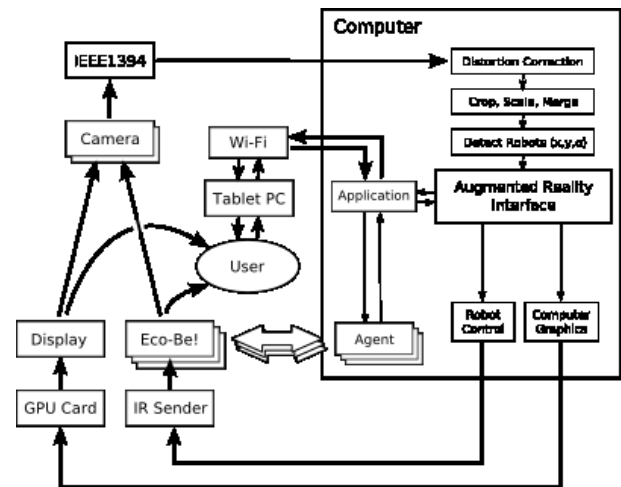


Fig. 5. Block diagram giving a general overview of the software architecture.

- ball diameter and its dynamics can be easily changed);
- Possibility for a large variety of creative applications that include, but are not limited to, soccer. Among the numerous conceivable applications there would be some which are almost (or completely) impractical to do with real robots if not for the aid of augmented reality (e.g. simulation of force fields, artificial webs, laser beams);
- Environment becomes more visually appealing, turning it interesting for the audience and for the media. This also allows the display of a variety of usually unseen features, making it also appealing for applications on a variety of new fields such as swarm intelligence (e.g. bug heat fields or ant trails can be shown) and artificial life (food, preys and predators can be simulated in big number and any shape);
- Robots would not be required to be equipped with extra sensors and could still enjoy complex models of the environment through the use of virtual sensors and actuators (e.g. virtual camera, heat sensors, kicking device, virtual grippers, etc.). Controversial enough, this removes the need for expensive/complex equipment to be installed in

the robots but actually extends the possibilities to the limit of imagination;

- Standardization of both software and hardware, making it possible to do benchmarks of different techniques used by different people in a straight-forward way;
- Portability, for the case of using a multimedia projector – 22 robots plus a projector could easily fit into a briefcase.

## V. THE PV ROBOCUP GAMES

Competitions would be held initially in an autonomous soccer environment similar to that of RoboCup Soccer Simulation league. A variety of competitions and challenges would be gradually included over the years covering a diverse range of fields in reflex to the general interest and quorum of development.

The platform is currently still highly experimental and the robots are to be delivered to the teams around the end of 2006, beginning of 2007. Therefore, the first competitions during the RoboCup in Atlanta, July 2007, are very unlikely to show very sophisticated performance. The teams will have nearly only four months to implement their code.

Nevertheless, for 2007 one would already expect to see:

- Six-on-six soccer games with virtual ball;
- Real ball technical challenges (pushing ball games);
- Demonstrations of applications in multiagent related disciplines. Focus on research and education;
- Open demonstrations, possibly showing the potential for real world applications;

## VI. CONCLUSION

We presented the CITIZEN Eco-Be! mini robot and described an original AR environment. This architecture was then propose as a standard for making a new versatile and affordable real-robot platform and RoboCup sub-league. Steady progress is being achieved in the improvement of the robots themselves, on the AR setup and on the integration of the physics simulation environment. The entire architecture is expected to be ready for being tested by 20 teams from all over the world already in Atlanta next year.

Following a fast pace, CITIZEN proposes long term development of increasingly more sophisticated Eco-Be! robots over the years. There is plenty of room for improvement in what regards to modern watch technology, including miniature devices for bluetooth, camera, etc. – the robots would be updated accordingly to the needs observed during the years. Furthermore, these robots may become part of CITIZEN's line of products, provided sufficient market acceptance and robust development becomes apparent over the years.

## ACKNOWLEDGMENT

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