# Post-Match Analysis Program for Robot Soccer

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**Abstract:** This paper details a program that has been developed for the post-match analysis of a robot soccer game, MIROSOT (Micro-Robot Soccer Tournament). What wins a robot soccer game is intelligent strategy, apart from good motion control, robustness in image analysis, wireless communication and hardware. To improve the strategy, one needs to analyse the game; one way to do that is video record it and then watch it later to observe the behaviour and performance of the robots. While this may help to some extent, it still does not help generate statistical data, like the work rate of the robots, to fine-tune the strategy.

Keywords MIROSOT, Robot Soccer, Simulator, Game reconstruction, Analysis programme, Game Statistics

## 1. INTRODUCTION

In any game involving the participation of teams of players, there is a certain element of strategy involved to win the game. The strategy employed greatly influences the player behaviour and performance. Thus the analysis of the game is done so that a coach and his players are able to improve the team dynamics and performance in subsequent matches. The analysis often involves scrutinising the player movements, calculating the work rate and other parameters like speed, distance travelled etc [1]. In recent years, significant research and development effort has been invested in developing an automated system for post-match analysis [2]. While a post-match analysis is certainly useful for future performance improvements, some match statistics, if available in real-time during the game, will be very effective in fine-tuning the strategy while the game is in progress [3]. It is common place these days for TV broadcast stations and coaches to use such software. However, most of these applications rely, to varying extent, on some form of human inputs.

There is great demand for a fully automated match analysis software. A big hindrance to developing such a system is the availability of a flexible test platform which may be used to authenticate the usefulness of the software. In order to test our match analysis software we have used the Robot Soccer System.

What applies to human version of soccer also holds true in a team game with robots even though it is in a different form - the players being robots and the coaches being programmers. The team performance is improved through the off-line modification of the strategy code or through tweaking certain parameters of the strategy during the game.

The system we describe here has many functions. During the game, the data output from the image processing layer, namely the position and angle of robots and ball, is stored in a file which is later used to reconstruct and simulate the game. This eliminates the need to video record the game. Additionally, the system can calculate the velocity of the robots in each frame, the total distance travelled and work done in a time window, the top speeds and average accelerations. A very important feature of the program is that it also produces graphs automatically so that the robots' performance can be visualized easily and quickly. This also helps to make decisions during the game such as replacing a robot player, or changing batteries of an 'over-worked' robot, tweaking game parameters and adjusting the strategy.

In section 2 we describe the robot soccer platform which has been used as the test bed. Section 3 details the various capabilities and features of the system, namely the raw-data viewer, game replay simulator, match analysis program and the graph generation respectively. Future development work is detailed in section 4 and we summarise our conclusions in section 5.

## 2. ROBOT SOCCER SYSTEM

Micro Robots are used in education and entertainment in many ways [4]. There are robots which navigate a maze, climb a wall, play a game of soccer, wrestle with another robot, run round a track, balance a pole, mow the lawn and vacuum clean the house.

Robot Soccer has become increasingly popular over the last decade not only as a platform for education and entertainment but as a test bed for adaptive control of dynamic systems in a multi-agent collaborative environment [5]. It is a very good replica of the human version of soccer, though often scaled down to between 3 and 7 players in a team to limit the complexity. It is a powerful vehicle for dissemination of scientific knowledge in a fun and exciting manner. It encompasses several technologies – embedded micro-controller based hardware, wireless radio-frequency data transmission, dynamics and kinematics of motion, motion control algorithms, real-time image capture and processing and multi-agent collaboration. Because of the dynamics and high complexity of the robot soccer system as well as manoeuvrability and high speed of its robots, the accurate and real-time detection of position and orientation of objects has gained special importance as it greatly affects path planning, prediction of moving targets and obstacle avoidance. It is thus also a good test bed for developing vision systems for real-time tracking of players which has been explored in [6]

Figure 1 shows the robot soccer system setup.

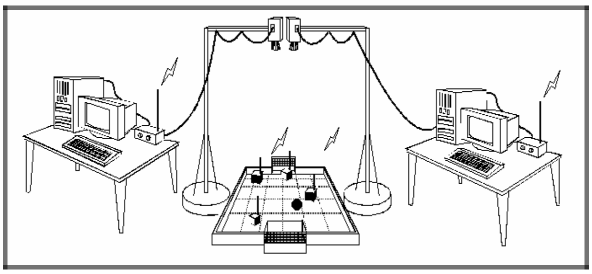

Figure 1. Robot Soccer System Setup

A camera is mounted at the top of the soccer field. Each robot from the home and opponent team is identified by a colour jacket mounted on it [7]. The hierarchy of the software is shown in Figure 2. The vision processing layer of the software determines the

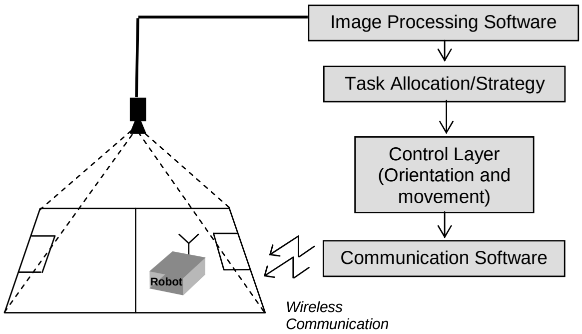


Figure 2. Software hierarchy for robot motion control

position and orientation of the player robots and the ball.

## 3. PROGRAM DESCRIPTION

The vision processing is done at the rate of 60 frames per second. In each frame the image is analysed and the data generated by the vision software, namely the robot position and orientation, is logged into a file which is subsequently used for various purposes. The four main functionalities of the program are the raw-data viewer, the game replay simulator, the game statistics calculator and graph generator.

### *3.1 Raw-Data Viewer.*

The raw-data viewer provides the 'coach' a comprehensive list of the data that is logged into the file. Figure 8 in Appendix shows a screenshot of the raw data viewer dialog box.

The data that is presented in the dialog box is the robot position (X and Y coordinates) in the current and previous frame, robot angle in degrees in the current and previous frame, and current angular velocities of the robots. The robot position is shown in screen coordinates (pixels) as well real-world coordinates (cm).

The user can scroll through the data by using the UP and DN command buttons. The number of frames through which the data is scrolled, the *step by* size, can be specified; the default is one. A user can also randomly seek to a particular frame data by specifying the frame number. While scrolling, the current frame number is also depicted. Also shown on the screen are the coordinates of the field, home goal and opponent goal boundaries. This data, however, does not change with each frame.

For a complete game of ten minutes' duration, the amount of data logged in is enormous. From the screen and real-world coordinates, a user really can not infer much about the game state and the robot positions. It was thus necessary to create software that could graphically recreate the game from the raw data. This game replay simulator is explained in the following section.

*3.2 Game Replay Simulator.*

Coaches traditionally analyse a game by watching the video recording. In the robot soccer system a camera is already in place which overlooks the field. It is very convenient to feed the video signal to a recording unit and record the game for viewing later. While this is a possibility, it is not entirely necessary, if the sole purpose of the recording is to analyse the game.

While the game is in progress, the vision software generates data pertaining to the robot (and ball) position and robot orientation. This data, which is stored in a file, is utilized by the game replay simulator to 'reconstruct' the game. Bit-mapped graphic images, representing the robots and ball, are generated and depicted on the computer screen. The location and orientation of the bit-mapped images is determined from the data for each frame. The field, home goal and opponent goal boundaries are also drawn using the data stored in the file.

The simulator has the advantage of not requiring additional video recording hardware. Other features of the simulator are:

- It can step through the data, frame by frame, and construct the scenes.
- The step size can be changed. To look at the game situation every one second, the step size should be set to 60.
- Able to advance as well as retract frames.
- Randomly seek to any frame and construct the scene.
- Free running game reconstruction in which the game is replayed in real time at the exact speed at which it was recorded (60 frames per second).
- Stopping the simulator at any frame.

Figure 3 shows a screen shot of the reconstructed scene for frame number 2115. The GUI control elements are also visible.

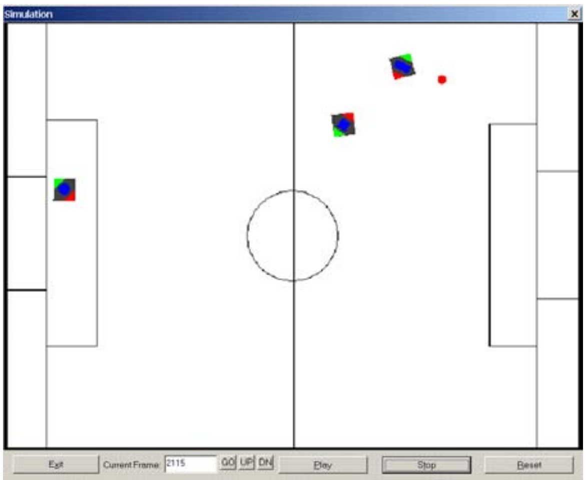


Figure 3: A screenshot of the game replay simulator

From a coach's perspective, the most useful feature of the simulator is the ability to step through the scenes frame by frame. This enables him to explain to his players the strategy and where it can be improved.

*3.3 Game Statistics Calculator.*

One of the objectives of the analysis program is to provide team members statistical information that would normally not be available from traditional video recording or would be very complex to calculate. For this reason a statistics calculator has been developed to perform as many of these calculations as possible and to present these in a text format that is easy to comprehend. This data is extremely useful for the coach to make critical decisions about player selection, role assignments and, in general, selecting a strategy for the team. Figure 4 shows a screenshot of the GUI for the game statistics calculator.

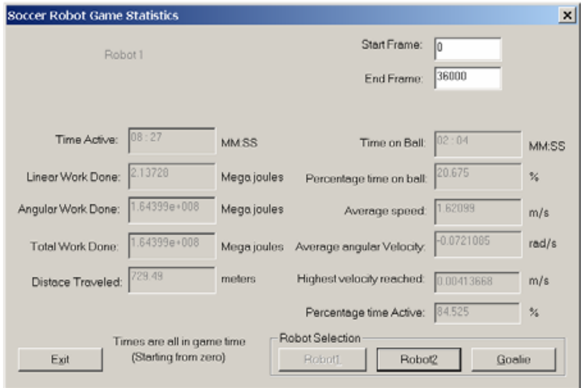


Figure 4. Screenshot of the game statistics screen

The analysis software produces the following statistics for each player –

- amount of time that the robot player is 'active' in MM:SS and as a percentage of the monitoring time.
- amount of time that the robot player is within an arbitrarily set distance from the ball (called *time on ball*) in MM:SS and as a percentage of the monitoring time.
- amount of rotational (angular) work done
- amount of linear work done
- total work done in Mega joules
- total distance travelled in meters
- maximum speed that the robot player attained during the game in m/s
- average speed (angular and linear) of the robot player during the game.

The game statistics can be calculated for the entire game or over a set of contiguous frames with an arbitrarily set start point.

In the game statistics calculator, the values are calculated using the standard physical formulae.

Work done = force x distance. (1)

Force = mass x acceleration (2)

Acceleration = Δspeed / Δtime (3)

Speed = Δdistance / Δtime (4)

### *3.4 Graph Generation.*

A great tool to use in the analysis of statistics is graphing. To this end the analysis program produces comparison graphs for all the game statistics so that one can compare the performance of the members of a team in all the areas that are being computed. These graphs are produced from the data that is logged into the file during the game. Graphs can also be custom produced; any of the variables may be chosen to be depicted in a graph. In fact, any combination of variables, within the boundaries of normal restrictions on graph type classification, is possible. This gives the coach tremendous scope to analyse every aspect of the game.

There are eleven different types of graphs that can be produced. They can be modified to have any title that is wished, or any axes labels.

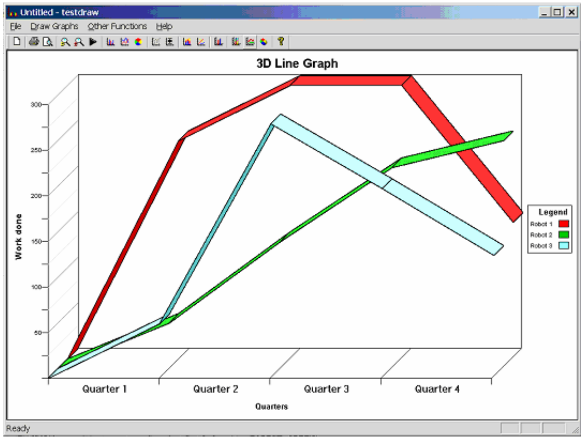


Figure 5: Work done by the robots, shown in a 3D Line Graph

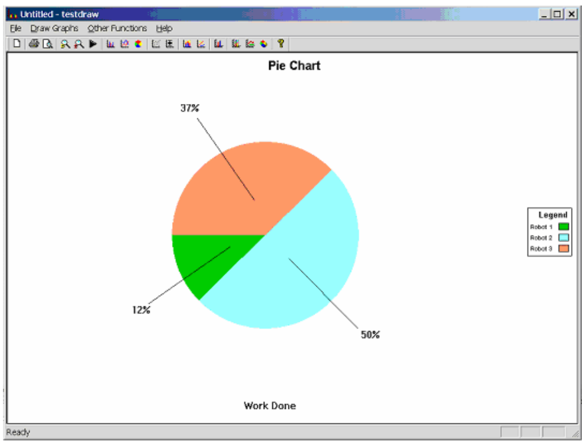


Figure 6: Total work done, as a percentage, by the robots in a game, shown in a Pie Chart

Figure 5 shows the work done by the three robot players of a team in four equal time intervals of a game. Figure 6 shows the total work done, as a percentage, by the robot players and Figure 7 shows the total distance travelled by the robot players.

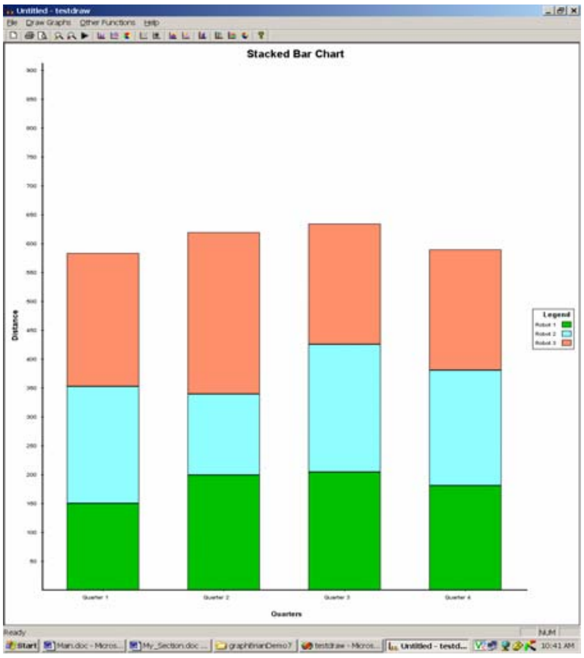


Figure 7: Distance travelled by the robots, shown in a stacked Bar Chart

## 4. FUTURE DEVELOPMENTS

This program gives an entry into the world of game statistics and analysis for the robot soccer game. Currently all the data is analysed after the game is over and so is only useful for the coach and players to improve the strategy for future games.

A real time analysis program would be much more useful, not only to the coaches and players but also to the spectators.

Another extension to the system that will be done in future is making the game data (robot/ball position and orientation) available on a remote station over the Internet. This will enable the game to be reconstructed in real-time on any remote computer connected to the World Wide Web and the match statistics to be generated on remote local stations. From the analysis data, a coach, stationed on a remote computer, should be able to tweak the game parameters and alter the strategy.

## 5. CONCLUSIONS

Robot Soccer system has been a useful test bed to develop systems for game analysis involving a team of players. This paper has described the post match analysis programme's functionality, namely the raw-data viewer, game replay simulator, match analysis program and the graph generation respectively. The system has been fully tested on a system with 3 robots in a team. It can be adapted for other team games like rugby and applied to the human version of the game. The biggest challenge in adapting the system for human version of the game will be the vision processing software.


## 6. ACKNOWLEDGMENTS

The authors greatly acknowledge the contribution from Dr. Donald Bailey, Institute of Information Sciences and Technology, Massey University, Palmerston North, New Zealand, for his advice on bit-mapped graphics.


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## 8. APPENDIX

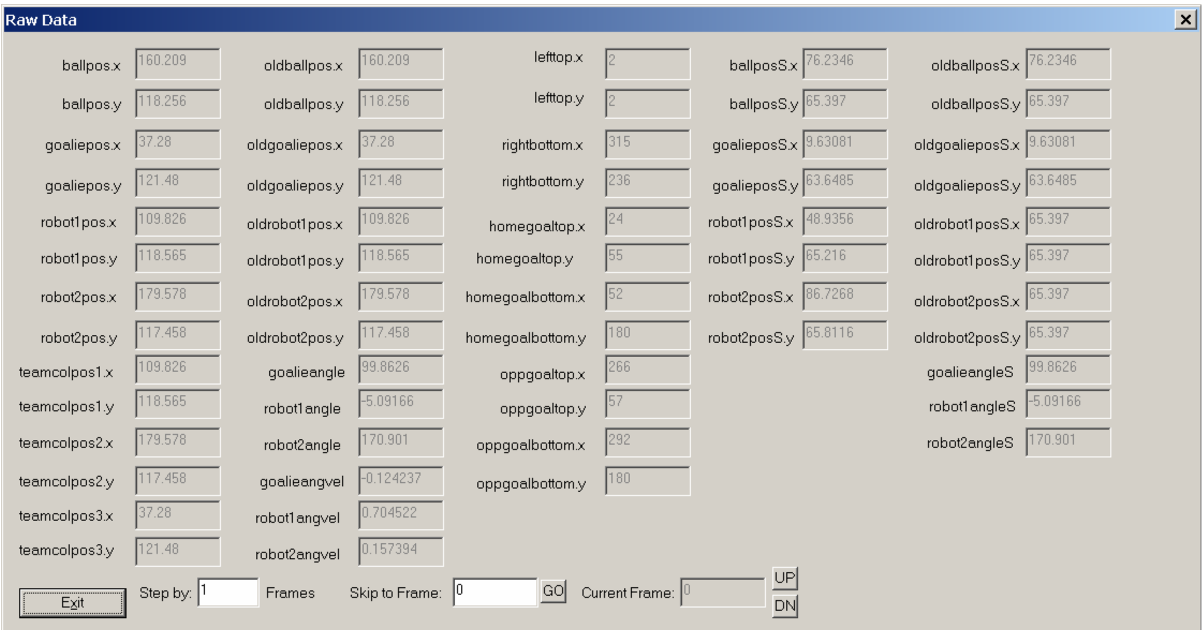


Figure 8: A screenshot of the raw data viewer.