

TRIGONOMETRIC WORLD STATE FUSION

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Abstract: In this paper an approach to data fusion for world state communication in RoboCup 4-Legged League is proposed. The trigonometric localization within a multi-agent system is presented, explaining its advantages and disadvantages when compared to the usual method of data communication in this robotic soccer league. It is also presented a method to dynamically decide when to use the new data fusion method, as well as a proposal for evaluating the effectiveness of the presented solution.

Keywords: Artificial Intelligence, Multi-Agent Systems, Four-Legged Robotic Soccer, Data Fusion, Co-operation.

1 INTRODUCTION

1.1 *RoboCup*

RoboCup is an international competition, created with the objective of promoting research on Distributed Artificial Intelligence and Intelligent Robotics (Kitano *et al.*, 1995). The objective that is held as final is the construction of a robotic soccer team that may be able to beat their human counterparts in a not so distant future.

This objective is merely a very distant dream. Great developments in robotics, artificial sensors and actuators and artificial intelligence methodologies must be accomplished for approaching that dream.

The RoboCup competition is held every year and is divided in several leagues. The leagues in the RoboCup Soccer branch are: Medium-sized robots, Small-Sized robots, Humanoid robots, 4-Legged-League Robots and Simulation League.

1.2 *RoboCup 4-Legged League*

RoboCupSoccer 4-Legged League (RoboCup Federation, 2004) is a league in the RoboCup Soccer competition that uses a standardized robotic platform. That robotic platform is Sony's AIBO robotic dog (Sony Corporation, 2004). Being a standardized platform, the teams must rely on software alone to achieve victory. The error prone mechanical sensors (odometry) and visual object recognition cause interesting challenges on how to deal with those inaccuracies, minimizing their effect.

The major contributions from this league to the long-term objective are principally in Multi-Robot/Multi-Agent Coordination, visual image recognition and robotic legged movement improvements.

Rules of the 4-Legged League

Each match of the league is played on a 3,1m by 4 m green field, containing 2 colored goals (yellow and cyan) and four localizing beacons (colored yellow, cyan and pink).

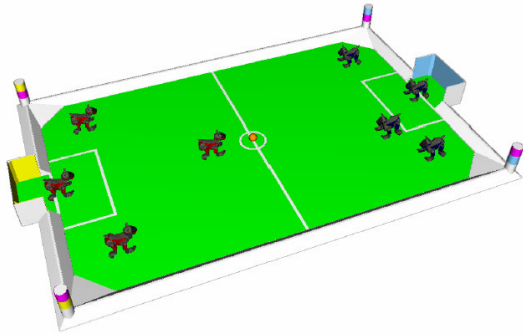


Figure 1 – Match field of the 4-Legged League

Each game is disputed in two 5 minute halves, being that the clock is stopped during stoppages of play.

No interaction with the robots is permitted to the team during the match. If the game ends in a tie, golden-goal is used to find a winner.

Wireless communications between the robots is permitted, with the only applied restrictions being a 2Mbps throughput and the wireless infrastructure being the one provided by the RoboCup organization.

1.3 AIBO Robotic Dog

The robots used in the 4-Legged League are limited to the ERS-210A and the ERS-7 AIBO models. Figure 2 shows the front and side view of the ERS-210 model (Sony Corporation, 2004), presently used by the team FC Portus RoboCup Soccer team. The robot has eight touch sensors:

- one for each leg, at the paw
- one in the back
- two on top of the head
- and one under the chin

Besides the ones stated, the robot has one sensor for each of the 19 actuators:

- Two for the tail,
- One for each ear,
- Three for each leg,
- Three for the head.

Beside the ones stated, the robot has one vibration, acceleration and thermo sensor.

For this document, it's important to focus on the Camera and the infrared sensor, has they are the only means to try to determine the ball position relative to the robot.

The camera has a 352 x 288 resolution, capable of a capture rate of 25fps, and is located on the front of the robot's head. Also in the same location, a infrared distance sensor exists. This can be used to measure, with a milimetric precision, distances from 10 to 90 cm.

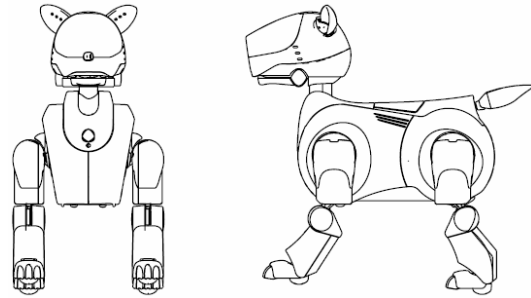


Figure 2 – Sony's AIBO Robotic dog ERS 210

2 WORLD STATE RELEVANCE AND CONSIDERATIONS

2.1 World State

The agent's internal representation of the world, resulting of the processing of the various inputs, is denomineted as World State. Considering the concrete case of soccer playing AIBOs, the ideal information that is contained in the world state includes:

- Self position – Cartesian coordinates;
- Ball position – Cartesian coordinates;
- Ball velocity - Vector;
- Colleagues' position – Cartesian coordinates;
- Colleagues' velocity – Vector;
- Colleagues' behavior;
- Opponents' position – Cartesian coordinates;
- Opponents' velocity – Vector;
- Opponents' behavior.

All the above measures are ideal, being that in the real world all the above measures would associate with an uncertainty factor (Russel and Norvig, 1995), expressing the probability of the measure being accurate.

Another idealistic measure it's the current behavior of opponent robots. There is research in the area of opponent behavior recognition, but this paper won't enter in those details.

This paper will focus on ways to improve ball positioning, based on sensor data from more than one agent.

2.2 Considerations concerning ball perception influencing factors

There are basically two major sensors for ball recognition: the robot's camera and the robot's infrared sensor.

Infrared Sensor

The infrared sensor included in the Sony's AIBO can measure from 10 to 90 centimeters, from the

front of the robot's head. Knowing the robot's present position and heading directly towards the ball, it's simple to determine the present position of it. Although this method is much more precise than the alternative, it also implies that the ball is close enough, as well as some visual method to recognize the object in front of the robot as the ball.

Camera

The use of the camera to determine the ball position and velocity implies much more processing, as a visual recognition of the ball is done by detecting a ball's color blob, and evaluating its distance to the robot by the size of the correspondent blob. Next, by knowing the position of the robot itself, and the direction of the head while looking directly to the ball, the ball position is determined.

Many errors come by the use of this technique.

One is the result of bad color calibration (or a changing environment), omitting the edges of the ball, and a correspondent representation of the ball too distant.

Others come by the fact that it relies of the assumption that the robot knows its position, which can be erroneous.

Finally, there are errors caused by the undetected partial occlusion of the ball by other field objects. These cause that the perceived ball blob size being reduced. The resulting ball position is farther away than the real position.

3 INITIAL BALL STATE FUSION ARCHITECTURE

To minimize the impact of the errors stated above, efforts were made to distribute de agent's ball information and uncertainty factor between the team, thus enabling the agent to prefer other agent representation of the ball, if with higher confidence. This is not truly data fusion (Durrant-Whyte and Stevens, 2001), as the various different possible positions of the ball are not combined, merely compared. Next, it will explore the idea of retrieving valuable data from the others agents' ball position and self position to enhance the agent self representation of the ball location.

4 TRIGONOMETRIC APPROACH TO BALL LOCATION

Figure 1 presents the simplified model of an agent seeing the ball. The big green circle represents the agent, the red circle represents the real location of the ball and the tiny green circle

the location of the ball calculated by the agent. The green ellipse is the area where the agent has 98% of certainty of ball inclusion. The reason for it to be elliptical is that the direction to the ball is far more easy to calculate precisely than the distance to it. Assuming that the self positioning is accurate, the direction to the ball is determined by the robot's neck orientation, while the distance relies on visual readings.

The dotted lines are the leftmost and rightmost directions in which the ball can be seen.

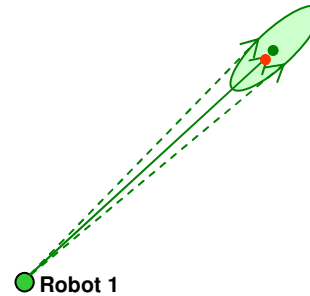


Figure 3 – Simplified agent view of the ball

In figure 2, another agent was included, as its own representation of the ball. Notice that there is still only one real position for the ball, but the blue representation of it is farther from it than the green one. If no improvement was made to the already existent methods of data communication, the blue robot would simply exchange his calculated location for the ball with the one received from his teammate.

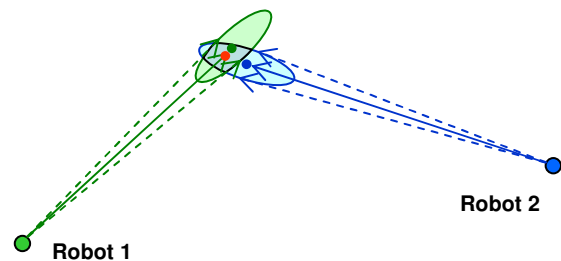


Figure 4 – Two distinct views of the ball

Now, what's proposed is that both robots use the other's information, while considering still their one. This is done by accepting that they may be both right, opposed to one being "more right" than the other.

To combine the information the assumed distance to the ball should be ignored (as it is more fallacious than the other measure, the direction) by both robots.

Then, each robot must intersect it rightmost and leftmost directions to the ball (considering not the particular assumed point of the ball, but the area of almost certain inclusion) with the rightmost and leftmost directions of the other agent. Then, having the area delimited by these four directions, we simply assume the position of the ball to be in the center of this area. The uncertainty factor of the resulting representation should be a result of the uncertainty factor for the ball of the two agents, and will be explained later.

The area definition and ball position is shown in figure 3 and figure 4. This area is utilized because the intersection between the information of both robots is more probable to contain the real ball position than the individual visual boundary area. Also the intersection area is smaller than the visual boundary area.

The calculated ball position is obtained by the calculus of the centroid of the obtained intersection polygon.

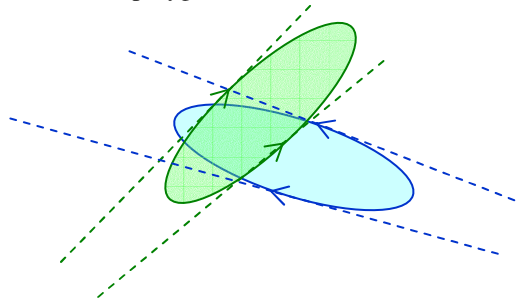


Figure 5 – Intersection of the ball probability shapes

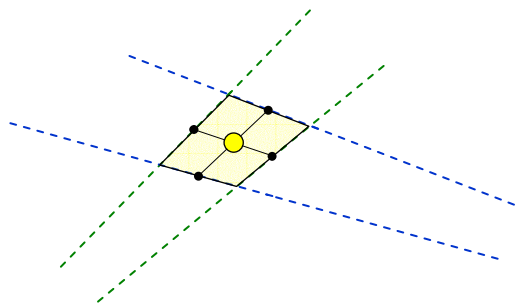


Figure 6 – Centroid of the calculated ball polygon

Finally, figure 5 presents the new calculated position of the ball relative to its real position. In the exemplified case, the new location is a more accurate one than any of the ones given by the

isolated



agent.

● Robot 1

● Robot 2

Figure 7 – Real and calculated ball positions

5 RESULTING UNCERTAINTY FACTOR

Until now, it has been assumed that the position of the robots was known, which is false. This position also has an uncertainty factor associated, which will be used to calculate the uncertainty factor of the generated fused ball. In fact, it will be also used to select which pair of agents will do the fusion.

6 DYNAMIC INTERSECTION SELECTOR

Each agent has a confidence in its own position. That confidence can be expressed as a circumference around its estimated position (Figure 6).



Figure 8 – Robot Position and the certainty circumference

The circumference represents an area in which the agent is located with a combined certainty factor of 98 %. From this affirmation we can extrapolate that the position of the agent can vary within that same circle.

Being that the vectors (rightmost and leftmost) towards the ball are calculated based on the assumption that the robot is at a defined point, we recalculate the rightmost and leftmost vectors as being the rightmost vector when the agent position is in the rightmost position of the certainty circumference, and being the leftmost vector when the agent is at the leftmost position of the certainty circumference.

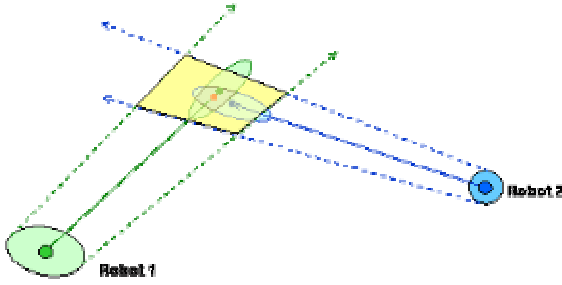


Figure 9 – Limiting area for the presence of the ball, in conjunction with the extreme vectors.

After calculating these new extreme vectors, the area defined between the interceptions of two of the agents quantifies the uncertainty of the calculated ball position (the bigger the area the bigger the uncertainty). This area is the limiting area for the presence of the ball according to the senses of the two involved dogs.

The Dynamic Intersection Selector calculates the referred area for each of the possible interception pairs, in conjunction with the possible area for the presence of the ball according solely to the current robot (this calculation hasn't been decided at this stage). After all the values have been calculated, it chooses what to do.

The criteria of selection are as follows:

1. If the ball velocity is higher than a certain threshold (to be determined experimentally), the time spent transmitting the data will render it useless. The agent uses its sensor readings;
2. Else if the robot's own ball certainty area is smaller than the obtained by any of the possible interceptions, then the agent uses its sensor readings;
3. Else, the agent uses the ball determined by the best interception, using the presented method.

7 ANALYZING IMPROVEMENTS IN AGENT COMMUNICATION

After implementing the above methodology for information sharing, based upon the theoretical ideas here stated, there's the necessity of testing the system. To accomplish a factor of comparison it's needed to have the real ball position in all moments during the analysis.

In order to obtain the real instantaneous ball position an overhead camera setup can be used, as long as the measures obtained by the measuring setup can be easily related temporally to the ones obtained in the AIBOs.

7.1 Data collection

The following setups must be used to generate enough data for reliable evolution detection

Single robot setup

Using a single robot in the field and moving the ball around, the instantaneous certainty factors of the ball are registered, together with the time they were measured, and the real ball position at that moment.

Robotic team using simple data fusion

Using the simplest fusion method described in the present document, the instantaneous certainty factors of the ball in each robot are registered, together with the time they were measured.

Robotic team using trigonometric data fusion

Using the simplest fusion method described in the present document, the instantaneous certainty factors of the ball in each robot are registered, together with the time they were measured.

7.2 Statistical data treatment

Using the collected data in each of the setups a statistical treatment is executed. The principal focus of this analysis is the calculation on the average certainty factor and error in each of the setups.

7.3 Statistical data comparison

After finished the statistical analysis, the obtained values are compared, drawing the conclusions if the proposed method is proven to be more effective than the others in minimizing the error.

8 CONCLUSIONS AND FUTURE WORK

Trigonometric World State Fusion is a different approach to fusion of world state information in four-legged league RoboCupSoccer.

Although a complete functional prototype of this methodology is not finished, the first experimental results of this methodology show that it may be very useful for our legged league robotic soccer team: FC Portus.

Future work includes finishing the prototype, developing a completely functional module to be included in our FC Portus RoboCup Soccer team for RoboCup 2004 international competition.

9 ACKNOWLEDGEMENT

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