SITUATION BASED COMMUNICATION FOR COORDINATION OF AGENTS

Rui André Ferreira * **Luís Paulo Reis** ** **Nuno Lau** ***

* *raf@fe.up.pt, University of Porto, Portugal*
** *lpreis@fe.up.pt, University of Porto, Portugal*
*** *lau@det.ua.pt, University of Aveiro, Portugal*

Abstract: In this paper we propose an approach to the problem of audio communication in RoboCup simulation league and other single channel and low bandwidth systems.
We introduce the Situation Based Communication concept, architecture, high-level decision algorithms and its integration with Situation Based Strategic Positioning.
We also propose a tool for an objective analysis of improvements in the precision of a simulated soccer players' world state. This tool can be used for testing communication strategies, perception strategies, behaviour models and other research topics that affect the agents world state.

Keywords: Artificial Intelligence, Multi-Agent Systems, Simulated Robotic Soccer, Communication Systems, Co-operation, Error Analysis.

1. INTRODUCTION

1.1 *RoboCup simulation league*

RoboCup is a research and educational initiative for the development of artificial intelligence and robotics. For this purpose, the RoboCup federation organizes, among other initiatives, the Soccer Simulation League.

The RoboCup Simulation League is based on SoccerServer [1] which has been used in several international competitions and research projects. Soccer is a very complex game, and the soccer simulator, although being a simplified two dimensional model of soccer, keeps its complexity and beauty.

The soccer simulation includes properties from the robotic systems combined with the real human soccer players. Time is updated in discrete steps. A simulation step is 100ms. During each simulation step, players and ball mantain their positions. Depending on the play mode, allowed actions will take effect.

This is indeed a very rich domain for the study of agent coordination and communication.

1.2 *The problem of audio communication in the simulation league*

Using the available *say* command [1], players can broadcast messages to other players. Players audio messages are received in the form:

(hear time direction TEAM [UNUM] "message")

if the message is from an element of the team or:

(hear time TEAM [UNUM])

if the message is from an element of the opponent team.

Messages can be 10 bytes long and can be heard within a distance of 50 meters by members of both teams. A player can only hear one message from each team per cycle.

Audio messages are applied in the end of the cycle. This means that if a player issues a message in the cicle τ, the message may be heard by other players at the beginning of the cycle $\tau + 1$.

Players are able to focus their attention on a specific player through the use of *attentionto* command.

(attentionto [team] [unum])

(attentionto off)

Messages from this player are heard in preference to all the others. If that player produces multiple *say* messages, one is picked at random. If that player produces no *say* messages, a message is picked from another player at random. If the *attentionto* command is not used, a message will be selected randomly from any player.

2. ANALYSING IMPROVEMENTS IN THE WORLD STATE

One of the fundamental aspects of a simulated soccer team is the quality of the player's world state. The better the world state, the better the reasoning can be.

So, it is crucial to develop a tool which gives an objective measure of the world state quality. This way it is possible to analyse the implications of vision, communication and decision changes.

2.1 *Object of analysis*

It is possible to determine agent's knowledge errors in this characteristics:

(1) Ball position, speed and direction.
(2) Player position, speed and direction.
(3) Teammates position, speed and direction.
(4) Opponents position, speed and direction.

It is possible to do this by logging the predicted value of this caracteristics in each agent and then comparing the result with the perfect world state obtained through the server log.

2.2 *The error concept*

The concept of world state error is not easy to define. The error from an object in the other side of the field can not have the same weight as the error from a object near the analyzer. Though there are many others factors that we can take in account besides the distance towards the object, they usually involve higher level concepts and imply a more complicated definition.

$$error_{obj} = \frac{|distance_{pred} - distance_{real}|}{max(distance_{real}, margin_{min})} \quad (1)$$

The error definition introduced in (1) gives a simple and effective value to the error but some caution must be held when $distance \rightarrow 0$.

2.3 *The importance concept*

The importance of a player's error to the team is also a concept it is worth to define. The error of a player which has the ball is more important than the error of a player far from the action. Again, higher level concepts like ball possession would be useful and a fuzzy logic approach which may have satisfactory results is under investigation.

$$imp_{ply} = \frac{importacy\_factor}{max(distance(ply, ball), margin_{min})} \quad (2)$$

$$distance(obj_1, obj_2) = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad (3)$$

Euclidean distance is in use, though other distances could also be efective.

2.4 *A measure of the world state quality*

A global, objective and quantitative measure of the world state quality is very important. This way, it is possible to see the implication of changes in wide areas as perception strategies, communication strategies or multi-agent organization and reasoning. One way of measuring this quality is doing an weighted sum of the world state characteristics mentioned above.

$$inst\_error_{ply} = \sum_{obj=1}^{nobjects} error_{obj} \quad (4)$$

$$inst\_error_{team} = \sum_{ply=1}^{nply} error_{ply} * imp_{ply} \quad (5)$$

$$total\_error_{team} = \sum_{cyc=1}^{ncycles} inst\_error * imp_{cycle} \quad (6)$$

The importance of a cycle may be considered constant or to be a function of the nearest goal.

3. COMMUNICATION SYSTEMS IN THE ROBOCUP SIMULATION LEAGUE

Before 2002 there were small constrains in the communication model. The say message was sent

Fig. 1. Game situation

immediatly back to players within 50 meters and its maximum size was 512 bytes. This model allowed approaches like ADVCOM by FC Portugal [2] or Locker-Room Agreements by CMUnited [5] and other similar approaches in which great parts, and sometime all the world state was communicated by an agent. With this specification, the world state of the players and by consequence its reasoning was very accurate.

In 2002, the communication model has changed as described in section 1.2. These changes had a drastical impact in the world state of the agents, leading to a less coordinated soccer. Due to the fact of hearing only a message per cycle, and having low bandwidth some principles for agents have been established:

(1) communicate only when it is useful from the team point of view.
(2) communicate only when it is believed that the utility of the communication is higher than the utility of the teammates communication.

Since then, these principles have been widely accepted and little research has been done in this area. *Prokopenko et al.* work on Entropy of Joint Beliefs is worth to mention [4].

Here, we propose a new and different approach which uses the *attentionto* command and does not follows the principles mentioned above.

4. INTRODUCTION TO SITUATION BASED COMMUNICATION

Ideally, if each agent in the cycle τ knew the information that every teammate communicates in the cycle $\tau+1$, he could use that information to choose the most useful communication and then he could pay attention to it. Obviously that is not possible, because it would imply knowing the communication before hearing it.

Player	*Message sent*
2	Player 2 position, direction and velocity.
3	Ball position, direction and velocity.
4	Player A position, direction and velocity.
5	Players B,1 positions, directions and velocities.

Table 1. Communications predicted

Player	*Message heard*
2	Players B,1 positions, directions and velocities.
3	Player A position, direction and velocity.
4	Ball position, direction and velocity.
5	Player A position, direction and velocity.

Table 2. Communications selected

However it is possible to do an aproximation of the ideal case. If each player has several situations defined and the type of communication in that situation is also defined, the other players in the game can use that information to predict his situation and therefore the interest of his communication.

This concept is rather simple, and it can easily be ilustrated with an example. Supose a game situation like the one represented in the Fig. 1 in which the yellow team uses Situation Based Commuication (SBC) as communication system. Though it could be diferent, supose that all the players have the same and following situation and respective communication definitions.

(1) If the player is the nearest to the ball, communicate ball position, velocity and direction.
(2) Else if the player is the last defensive player then communicate position, velocity and direction of players that are in harmful positions.
(3) Else if the player has good overview of the action zone communicate position, velocity and direction of the players involved.
(4) Else communicate self position

Given this rules it is possible to predict what each agent communicates in the cycle τ. This prediction can be analysed in Table 1.

As we predicted the communication of each player, each agent can do the same because he has an aproximation of the situation in which his teammates are. Then the agent can evaluate the interest of each one of the communications and then he can pay attention to it.

In the example, a interesting selection of communication to receive in the cycle $\tau+1$ would be one as described in Table 2

This is a great improvement to the standart communication approach. In the game situation analysed, to avoid message overlaping, probably only one player would communicate and probably that communication would only be useful to some of the players.

Situation Based communication can be resumed by the following advantages:

(1) In each cycle every player receives a message.
(2) There is no chance of message collision.
(3) It is the receiver and not the emitter who evaluates how intresting the message is.
(4) Players hear less redundant messages.
(5) Players can coordenate perception and action knowing what kind of information they are going to hear in the next cycle.

These advantages make SBC an innovative, efficient and effective approach for use in RoboCup simulation league and with practical aplications in single channel and low bandwidth systems.

5. SITUATION BASED COMMUNICATION FORMAL DESCRIPTION

In Situation Based Communication we use concepts like Communication strategy, Situation, Communication type, Communication Protocol and Communication format.

Definition 1. A *Communication strategy* is given by a set of Situations and respective Communication types.

Definition 2. A *Situation* regards the combination of conditions and circunstances at a given time of the game.

A situation can be active, positional or a game phase. An active situation is a situation that is conditioned by the relationship between the agent and a moveable object of the field *(e.g. Player is near the ball)*. A positional situation is a situation that is conditioned by the position of the player in the field *(e.g. Player is in the defensive midfield)*. A game phase is a situation related to the development of the game *(e.g. Game in the first half, Two goals difference)*.

Definition 3. The *Communication type* specify the nature of the information in a communication.

Definition 4. A *Communication protocol* is a set of Communication formats.

Definition 5. A *Communication format* is the arrangement of the data in a specified message.

In Fig. 2 it is possible to see the structure and organization of the Situation Based Comunication and its connection with Situation Based Stategic Positioning.

Situation Based Strategic Positioning is a system proposed by FC Portugal in [2] for coordination of a multi-agent team. This positioning system has great aplications in RoboCup soccer simulation and is being used by the most successful teams in the league.

The integration of Situation Based Comumnication in Situation Based Strategic Positioning simplifies the communication system integration on most soccer simulation league teams. It also makes possible the use of concepts like Dynamic Positioning and Role Exchange [2].

6. AGENT COMMUNICATION ARCHITECTURE

6.1 *Incoming communication decision module*

After the initialization of some internal structures, including the loading of a configuration file in which the pairs situation communication type for each position are defined, the agent enters in the main incoming communication loop.

As Fig. 3 shows, in this loop, the agent starts by analyzing the situation of every teammate within the communication range. As stated before, a situation can be *active*, *positional* or *a game phase*. There is no need to define none overlapping situations, because we propose a hierarchic model which verifies the inclusion in situations from the most restricted to the most general case.

After knowing the situation of his teammates, the agent knows the type of communication emitted by each one of them and then he can estimate its interest.

The agent chooses the most interesting communication using the *attentionto* command. In the following cycle the process loops back.

6.2 *Outgoing communication decision module*

There is a need for initialization of some data structures. As some of this data is the same as in income module it is possible to initialize it in both modules simultaneously.

The detection of the situation can use the same hierarchic process used in the incoming module. Note that usually the detection of the agent situation has good precision because in the general case, the agent has accurate information about his position and role in the field.

After the detection of situation and respective communication type, the key process in the outgoing communication module is the selection of the message format.

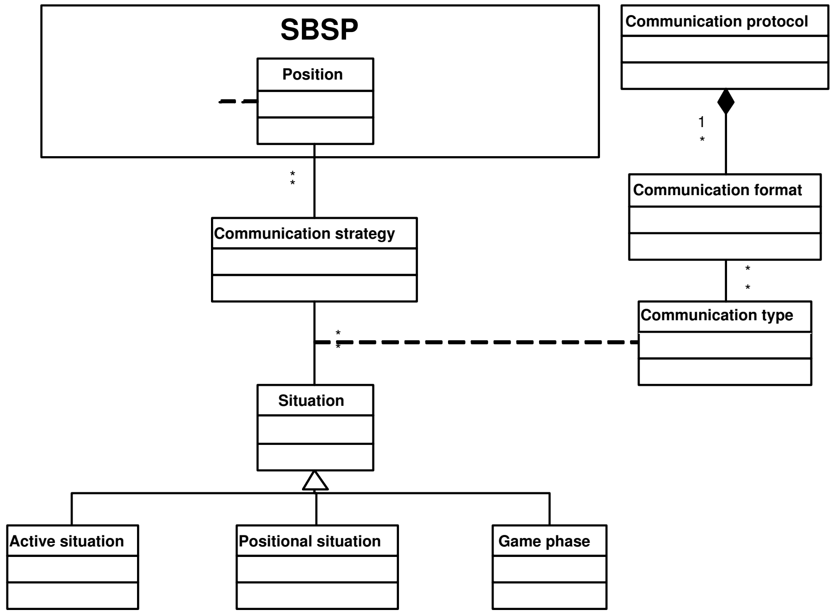

Fig. 2. Class diagram of Situation Based Communication

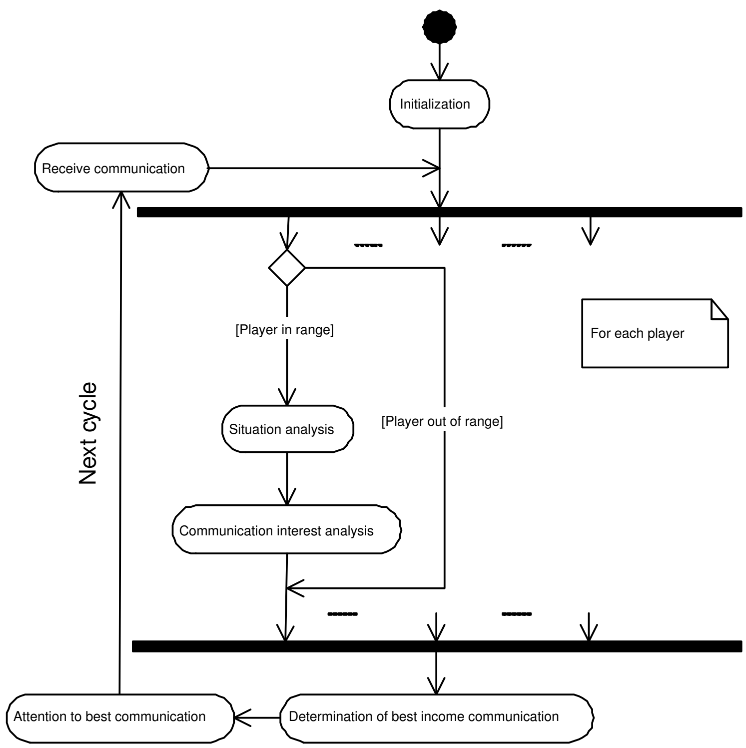

Fig. 3. Incoming communication decision process

There are some orientations that, if followed by the emitter, can lead to a good use of the communication system.

(1) Communicate information that the agent is confident about.
(2) Communicate as much data as possible.
(3) Communicate the data as precisely as possible.
(4) Communicate high level actions that can cause big world state changes.
(5) *Never* waste bandwidth, if the communication type can not occupy all the message communicate other important information.
(6) Communicate after sending the action to server and predicting the world state in the next cycle.
(7) Communicate every cycle.
(8) Communicate as late as possible.

Due to the very small size of the messages it is crucial to do a good exploration of the bandwidth. In the next section we'll discuss message formats.

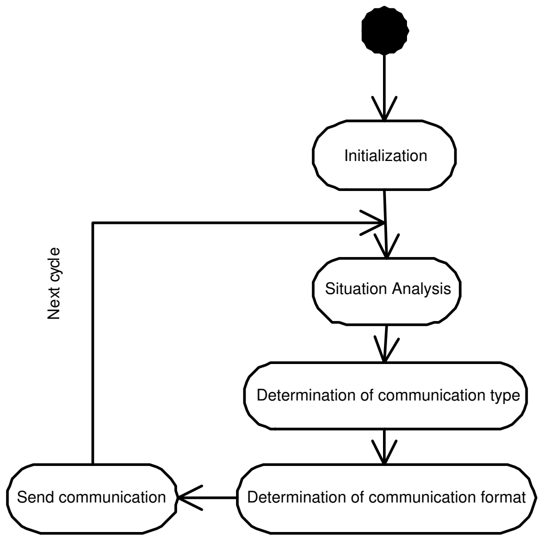

Fig. 4. Outgoing communication decision process

6.3 *Messages format*

As mentioned above, the simulation league model defines only 10 bytes as maximum size for messages. This fact causes difficulties in the transmission of the desired information. So, it's necessary to explore until the very last bit of the message to maximize the information encoded.

There are several kinds of information which may be useful to send:

(1) Confidence in each information.
(2) Position of an object in the field.
(3) Velocity of an object.
(4) Distance of a player to the ball in cycles.
(5) Ball possession.

Besides that, every message must contain a tag specifying the format of the message and an error check code because an erroneous message can cause major damages in the world state of an agent.

7. RESULTS

The Situation Based Communication is currently under implementation in FC Portugal 2004 simulated soccer team. The first results are very encouraging, and great improvements in the quality of agent's world state are expected.

Using the World State Analyser tool described in section 2, it is possible to obtain an objective measure of the impact of Situation Based Communication implementation.

8. CONCLUSIONS AND FUTURE WORK

Situation Based Communication is an innovative approach to the problem of communication in single channel connections. Applied to simulated robotic soccer, this technique allows an agent to receive the most interesting message sent by his companions in every cycle of the game.

Practical uses of this concept may be applied in wide areas. One of this examples is radio or television networks. If the receiver knows the program of all available emiters he can decide what to see in any moment. If the receptor defines a set of rules stating his preferences this process can be automatic.

Some radio networks do a small aplication of the concept in Radio Data System (RDS), Traffic Announcement (TA) and News Announcement (NA). If the listener is hearing a CD and the selected radio station starts emitting traffic or news, he is alerted.

9. ACKNOWLEDGEMENT

This research is partially supported by the Portuguese National Fundation for Science and Technology FCT-POSI/ROBO/43910/2002 Project - "FC Portugal - New Coordination Methdologies applied to the Simulation League".

10. REFERENCES

[1] Chen, M et al., Robocup Soccer Server manual, 2002.

[2] Luis Paulo Reis and Nuno Lau, "FC Portugal Team Description: RoboCup 2000 Simulation League Champion", RoboCup-2000: Robot Soccer World Cup IV, Peter Stone, Tucker Balch and Gerhard Kraetzschmar editors, LNAI 2019, 29-40, Springer Verlag, Berlin, 2001.

[3] Luis P. Reis, Nuno Lau, Eugénio C. Oliveira, "Situation Based Strategic Positioning for Coordinating a Team of Homogeneous Agents", Balancing Reactivity and Social Deliberation in Multi-Agent Systems, Markus Hannebauer, Jan Wendler, Enrico Pagello, editors, LNCS 2103, 175-197, Springer Verlag, 2001

[4] Prokopenko, M., Wang, P., "Relating the Entropy of Joint Beliefs to Multi-Agent Coordination", in the Proceedings of the 6th International Symposium on RoboCup, 2002.

[5] Stone, P., Veloso, M., "Task Decomposition, Dynamic Role Assignment, and Low-Bandwidth Communication for Real-Time Strategic Teamwork" in Artificial Intelligence (AIJ), 1999.