Holon - Like Approach for Robotic Soccer

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Abstract. The concept of "holon" coming from the industry (intelligent manufacturing systems) has been proved to be very successful in increasing the flexibility of decisional systems. While MAS (multi-agent system) are already largely applied in such systems, in this context, simulated soccer (RoboCup environment) becomes a test bench for further challenges. The paper describes a generic architecture for a RoboCup team with four holon types situated on three levels and based on the MAS architecture implemented in 1999 for the team that took part at the RoboCup 1999 competition in Stockholm. This architecture tries to combine synergistically the characteristics of both domains: MAS and HMS.

1 Introduction

Multi-agent systems (MAS) are software systems composed of several autonomous software agents running in a distributed environment. Besides the individual goal of each agent, global objectives are established committing all or some agent groups to their completion. This type of system is widely used in implementing teams for robotic soccer (RoboCup).

Another approach to this problem can be based on Holonic Manufacturing Systems (HMS). Holonic manufacturing is introduced as a new way to approach the manufacturing control problem (Van Brussel, 1994).

The concept of "holon" has been proved to be very successful in the industrial process planning, increasing the flexibility of decisional systems. It was proposed by the Hungarian philosopher A. Koestler (1967,1978) and explains the importance of the hierarchy of a system. Each organ is an element of the organic system while the organ is itself a system composed of multiple tissues. This relationship appears at every level of the system. This means that a system element is located at a hierarchy node and has both characteristics as a whole and as a part. Koestler named the node of hierarchy "holon" (Hino R. 1999) based on the combination of the Greek word "holos" that means "whole", and the suffix "on" meaning particle or part. Accordingly a "holarchy" is "a hierarchy of self-regulating control building blocks (holons), which function (a) as autonomous wholes in supra-ordination to their parts, (b) as dependent parts in subordination to controls on higher levels, (c) in co-ordination with their local environment."

We try to use such an architecture applying MAS approaches in the HMS framework. In this context simulated soccer (RoboCup environment) becomes a test bench for further challenges.

The remaining of this paper is organized as follows: Section 2 summarizes the strengths of this new architecture. Section 3 details the architecture and explains our generic holon. Section 4 describes the implementation. At the end, Section 5 draws some preliminary conclusions and future work is hinted to.

2 Why are we using holarchies?

Currently, AIResearch prepares a new team for the RoboCup competition based on new ideas and concepts. The approach is based on the holonic concept, and our idea is to adapt this new concept to robotic soccer. In our project this concept allows us to build a better model for the player-team-coach ensemble. In this section we will try to explain our choice.

By definition, the holon is an excellent concept for modeling a soccer team because of its main characteristic: it can act as a part (modeling a player) or as a whole (modeling the team).

One of the most important characteristics of the holarchies is the capacity to modify themselves, i.e. to create temporary hierarchies (Giebels, M. et. al. 1999). Like modern industry, the soccer is very dynamic, i.e. not only that each team comes with its own style and game strategy, but also each game phase has a dose of novelty. In this way, it isn't possible to create only one command scheme that will work correctly for each opposing team and each game phase. The holarchies aren't rigid, they change themselves according to necessities (strategic and tactic) and the structure of the decisional schema will change itself dynamically (by modifying momentary priorities).

Another advantage of using holons is that they offer a balance between the two possible approaches to the guided process: the hierarchical control (fixed, static, pre-established) and the heterarchical one (autonomous, decentralized, flexible but not very efficient) (see Fig. 1)

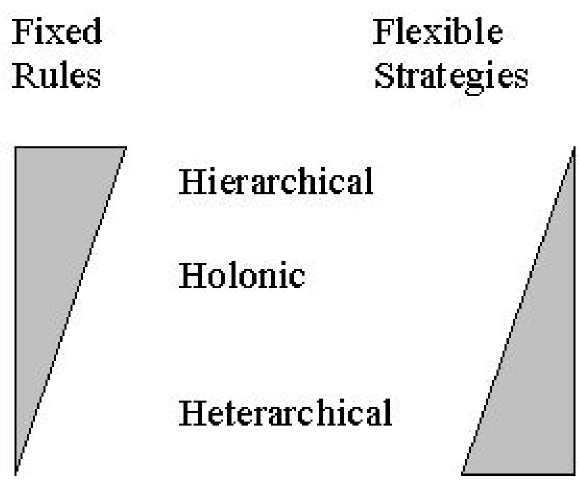

Fig.1 Holarchy

In the case of holarchies the problem (game phase) solving doesn't begin with the highest hierarchical layer, but directly from the place where it arrives - possibly from the lowest layer, and the superior levels are concerned only in so far growing complexity implies it.

3 Architecture

Using the holarchy properties (temporality and multiplicity) with this architecture we try to improve flexibility of the decisional model of our previous team "Sibiu Team" in Stockholm 1999.

Our idea is inspired by the PROSA architecture developed at PMA/KULeuven as a reference model for Holonic Manufacturing Systems (Van Brussel at al.

1998, Wyns 1999). The acronym PROSA came from Product-Resource-Order-Staff Architecture, the holon types used. The resource holon contains a physical part namely a production resource of the manufacturing system, and an information processing part that controls the resource. The product holon holds the process and product knowledge to assure the correct making of the product with sufficient quality. The order holon represents a task in the manufacturing system. It is responsible for performing the assigned work correctly and on time. The staff holon is implemented in the idea to assist the rest of three holons in performing their work.

At the first level we have the "RoboCup environment" containing the soccer server rules (Cortner et al. 1999, Noda et. al. 1998).

The coach is the most complex level of our architecture; conceptually, the coach combines the features of a soccer-team coach with the more complex goals and methods of a "coach" dedicated to computer supported collaborative work (Zamfirescu, C.B. 1998). Its holons try to acquire strategic and tactical information from past games (in the training sessions), they also train the players, monitoring and advising the player in the real game, and in the future, when it will be possible to change the players dynamically, it will select the players. At the player level are the holons who handle the resources (i.e. player stamina), implement the skills (i.e. pass, dribble, score), model the game tactic and coordinate the body parts in the future.

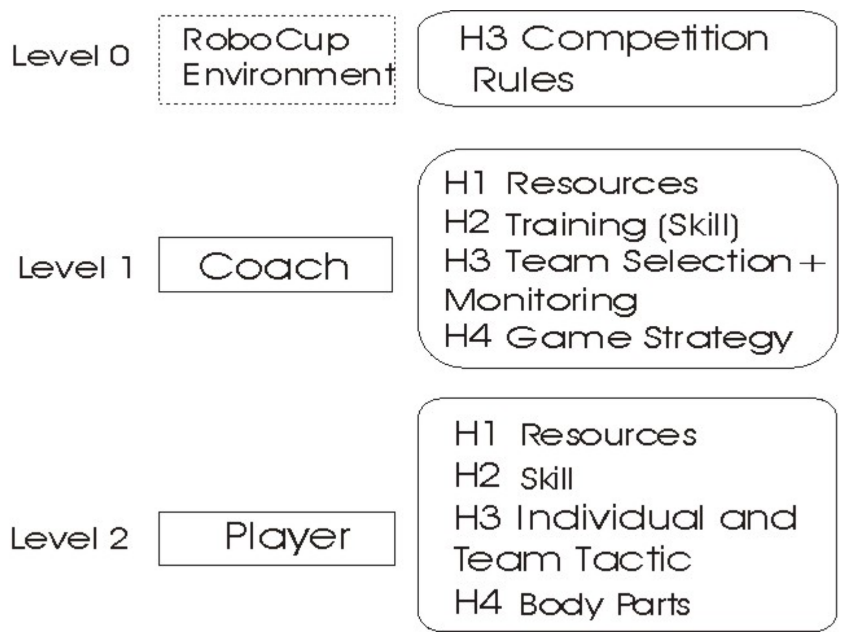

Fig. 2 Holonic Architecture

All these levels should be understood as a holarchy, not as a hierarchical organization.

A more detailed description of the holon functionality is in the next section, here being presented only the general holon structure.

A holon is the fundamental part of any holarchy, and it can be referred to as an agent who has outspoken cooperation and autonomy characteristics.

The holon has two communication channels with the outside world, as it can be seen in Fig. 3. One of these channels is used for communication with the other holons and the other one for acquiring information from the environment. The reactive layer - obviously indispensable - underscores one of the main common features of holons and agents.

The most important part of the holon is the planning process set up in the deliberative layer. The planning process uses data acquired through the two communication channels: a) with the environment (receiving stimuli and reacting to them), and b) with the other holons (taking advice from the higher level, negotiating with adjacent holons, monitoring subjacent holons).

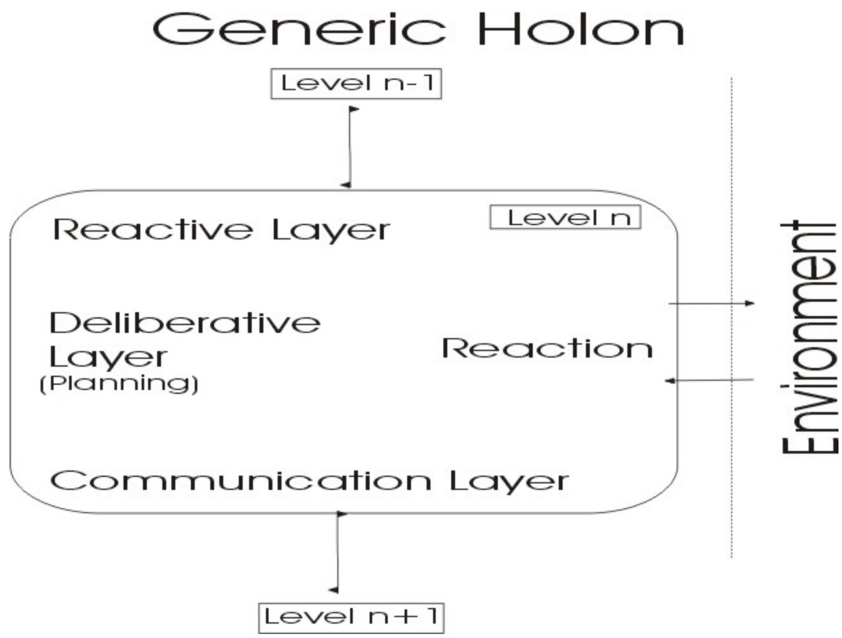

Fig.3 Generic Holon

The negotiation part (implemented in the communication layer) is activated in two situations. The first situation is when it receives some advices that can't be accepted (executed); in this situation it can inform the caller what can be done (i.e. it has other tasks more important for it or it can't implement the advice because of lack of capacities). The second situation is when it sends an advice to another holon and receives a rejection. Based on this refuse it can begin the negotiation process, which consists in redefining the advice (less requirements) or in task decomposition (it will try to assign more holons to solve the initial task).

4 Implementation

As we mentioned earlier, our architecture is based on the PROSA model where each holon has a well-defined functionality. The holons that we use have similar functionality as the original (Table 1).

PROSA	RoboCup	Coach	Player
Product	-	H2	H2
Resource	-	H1	H1
Order	H3	H3	H3
Staff	-	H4	H4

Table 1. RoboCup - PROSA holon similarity

The coach resource holon (H1) deals with the players from its team (e.g. simulation cycle). For the player this holon handles his stamina and simulation cycle.

The coach product holon (H2), in offline mode, has to generate game situations and tries to decide if the players' skills are acceptable. If those skills fail it will inform the development team (if the skills are implemented using analytical methods - as we have done) or will try to increase training the player (if the skills are implemented using neural networks or other methods suitable for automated training).

In the case of a player the H2 implement his physical skills (ball interception, ball handling, passing, shooting) using analytical methods.

The order holon (H3), when the coach is in off-line mode has to analyze previous games of the adverse team, gather useful information, create strategies and train his players accordingly, is the advice supplier for the other holons and assures the communication with the development team. In on-line mode it has to change the players when needed (not available yet), monitor the field situations and help the team in recognizing fixed phases. For the player, this holon implements his behavior using a knowledge-based system similar with the one used last year (Candea, C 1999) for ball handling and also for getting the ball (it implements several predicates i.e. CanSeeBall, BallKickable, OffsidePosition). Moreover, this holon implements the cooperative planning (information available at this layer is distributed among all team members) and provides the strategic positioning on the field using a neural network (Candea, C 1999).

The staff holon (H4) when the coach is offline has no role yet. In on-line mode it analyses the team behavior and tries to find some solutions. For the player this holon has to coordinate the body parts (left and right leg, arms, head) when a 3D soccer version will be available (this holon will be useful if the whole system has to coordinate a humanoid robot).

In the next figure (Fig. 4) we represent our player implementation. There are three layers: - reactive, deliberative and communication. Each layer is composed from the similar layer in the four holons. We try to explain this model with the aid of a short example.

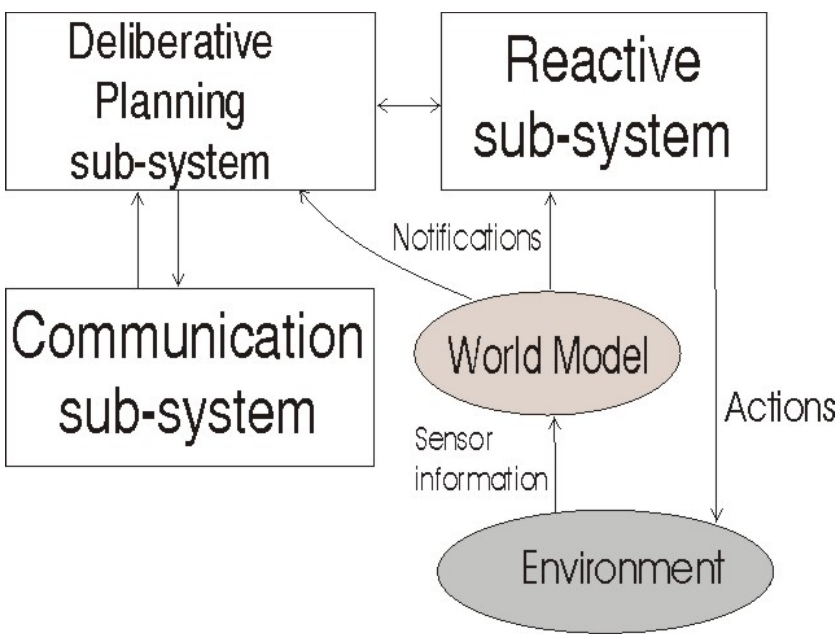

Fig. 4 Player system relations

The sensor information, received from the soccer server, is used to update the player's world representation (the World Model). When a significant change occurs, several notifications are sent toward the reactive and deliberative sub-system. These sub-systems try to modify their current actions (if possible and the changes aren't too big; i.e. when the player intercepts the ball, it may be necessary to slightly change the direction and/or the speed) or will cancel the actions (i.e. when the player tries to intercept the ball, but a referee message is coming) and will begin another one, more suitable for the new situation. In the decision process needed to select the new action, the communication has an important role. It facilitates the negotiation process between the four holons of a player and between the players. Between the holons of the player there isn't yet a real negotiation. A real one is implemented only among the players. We use a priority-based model, with two priority types: static and dynamic.

5 Conclusions and Future Work

In this paper we propose a new architecture that tries to combine in a synergistic manner the approaches applied in two, up to now insufficiently related domains: MAS and HMS. The preliminary results suggest that we are in a promising starting point for future work (the new team won all the games played against the 1999 team). This validates the approach of adding functionality stepwise (first of all, flexibility), i.e. improving the 1999 architecture. Following the tests we intend to introduce a new level between the coach and the players - the team level. With this new level, we think that the architecture flexibility will increase substantially. For the game strategy the order holon is still insufficiently adapted. The staff holon will be useful when the evolution of the game rules will give en even more substantial role to the coach - as resulted from the orientations given in Stockholm 1999 (Iozon, G. 1999). For the player this holon is useful in a 3D environment (either 3D soccer server version or humanoid robot). Another problem for the future is improving negotiation between holons.

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