

Report of an exchange funded by PerAda between:

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## **Spatial Self-Awareness in Replicator**

Replicator is a project about multi-agent, self-programming, self-assembling evolutionary robotics, coordinated by the University of Stuttgart together with Symbion, another European project closely related to it. The presence of the two projects in the same place created an environment where a group of more than 73 researchers can profit from the synergies of the respective works.

Because of the relevance of the goals the Consortium set, a close relationship between the members of our research community is of utmost importance.

In the following it will be presented an introduction to my work, also explaining how the exchange period funded by PerAda helped me to improve the obtained results.

### **Objective**

Formalize how to theoretically and practically achieve different level of self-awareness. In particular, the work focused on the Spatial Self Awareness (SSA) of the robot organism, both in the assembled and unassembled phases.

### **Introduction**

Awareness is one of the most interesting challenge in the Pervasive framework. As reported in papers like Ferscha "*Spatial Awareness of Digital Artefacts*", Tawfik "*On Middleware Support for Motion Awareness*" and Padovitz, Loke and Zaslavsky "*Multiple-Agent Perspectives in Reasoning About Situations for Context-Aware Pervasive Computing Systems*", the concept of awareness is multiform and is adaptable to different situation.

Deeper into the definition of Awareness arises the concept of Spatial Awareness (SA) SA can be found from military situation analysis (Kettani, Roy "*A Qualitative Spatial Model for Information Fusion and Situation Analysis*" and Shi, Barker, Alhadj "*Cognitive Information Fusion of Georeferenced Data for Tactical Applications*"), to sensor networks (Schon, Sick, Strassberger "*Hazard Situation Prediction Using Spatially and Temporally Distributed Vehicle Sensor Information*"), and many other examples of Ubiquitous Computing (Holzmann, Ferscha "*Towards Collective Spatial Awareness Using Binary Relations*").

Focusing on the point of view of the individual, the Self, it is possible to understand the concept of Spatial Self Awareness (SSA). SSA can be defined as the capability of the organism to feel the position and the space it occupies in the environment, and to know the functional properties of its body (i.e. physical constraints like joints, achievable velocity, etc...).

All the things that are not part of the Self, are part of the Non-Self. In general, the Non-Self can be explained as the reality that exists outside the Self. In most of the cases it is possible to resume that point of view using the concept of environment. The ability to notice, interpret, and use those changes can be called Environmental Awareness.

Analyzing more in detail the concept of Self Awareness, it is possible to find other two typologies:

- Temporal
- Emotional

Temporal Self Awareness (TSA). A being expresses this kind of awareness when it is able to manage time, creating a model of the dynamic of his past, present and future actions and thoughts. It is not always possible to abstract the organism from the space where it lives in, but it should be remembered that the point of view is centered on the being, not the environment itself. For instance, if a person is trying to avoid a ball that is far from him, he predicts the direction toward the ball is moving and he moves his body with a certain velocity depending on the velocity of the ball and the time that he knows he can move his legs (he will chose whether moving quickly and spend a lot of energy or moving slowly and save it).

The Emotional Self Awareness (ESA) of a being expresses its ability to process, investigate and evaluate its emotional internal states. A person who analyses his feelings, like the rage he feels for a certain behavior he assumed, shows ESA.

The boundaries between the three awareness are faded, as the boundaries between them and the environmental awareness, as shown in Fig. 1.

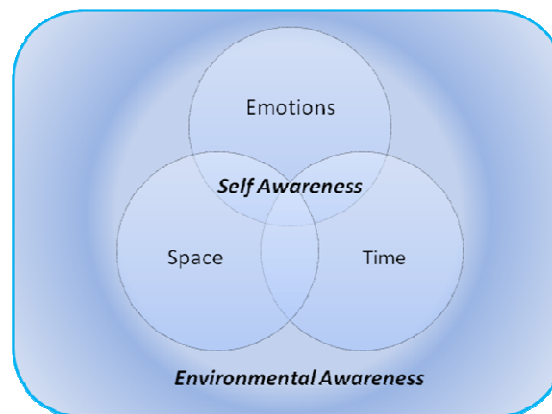


Fig 1. Representation of the subfields of Awareness

It is worth to notice that Self Awareness and Environmental Awareness can be expressed at many level of the mind. To be able to perceive the fatigue, for instance, is part of self awareness, but it's not strictly dependent on a conscious mind activity: it is simply perceived. Another example is the following. If a person gets focused, he can perceive in his mind the position of his right hand in the space. While, he cannot perceive without moving them the constraint imposed by his joints, even if he has a clear idea in mind of the range of movement that he can achieve.

### **Contextualizing SSA**

As explained, a being can express SSA. But, SSA it is not related just to a single being, it can be applied to groups of beings. Taking humans, sports are an example of activities where SSA is shown. The idea is to think that **a multi-agent system can be modeled as a being whose parts are the single agents**. This happens a lot of times in nature, as reported for insects in the book *"The Superorganism: The Beauty, Elegance, and Strangeness of Insect Societies"*. Thus, SSA is a concept expandable to a system rather than a single agent. Because Replicator is a multi-robot system, the work focused on the latter definition.

To define more sharply what SSA is, it is possible to get inspiration from the experiences of everyday life. An example of scenario where SSA is applied, could be an action during a basketball match. The mental processes a player relies on, are the same that a robot could use to express SSA:

1. Knowledge about the size and the performances that his body has (i.e. moving velocity, reaction times, degree of freedoms of the joints, etc...)
2. Knowledge about the disposition of the team on the field (the topology).
3. Ability to infer information regarding the spatial features, like the position of the other team members
4. Ability to extract features from the environment, like the disposition of the members of the enemy team
5. Ability to mentally codify those features
6. Ability to share information, like the features or inferred ideas, with the other mates.

It is important to point out that to achieve something that can be called “awareness”, it is needed to create a software module that will act as a unique entity, even if developed by recurring to different methodologies and approaches (because all the problems above have a proper literature and, then, a relative way to solve it without considering the other problems).

### ***The exchange***

The aim of point 2 is to create control and support functions to handle the disposition within the organism. This topology manager must be interfaced with the behavioral controllers to give support to their decisions. Thus, the information has to be codified so that just salient points, we could say the properties of the net, will be elaborated.

The topology manager will result from the sum of different features. Some of them are reported in the following list:

1. Deploy the robots in the swarm phase in regular lattices (squares, hexagons,...). Those basic lattices will aid the assembling phase and the achievement of the latter points.
2. Coordinate the movements of the unassembled organism, so that it will move as a unique being.
3. Create specific geometrical patterns within a group of robot, assigning to them certain properties given by the particular disposition.
4. Combination of those patterns to obtain new properties, from both the actuative and the sensorial point of view.

During the visiting period in Stuttgart I had the opportunity to discuss with many researchers from the Institute of Parallel and Distributed Systems about those topics. In particular, I shared the most of my time with Florian Schlachter, that I want to thank for the profitable talks, the constant support and the kindness.

The visiting period strengthened the reciprocal knowledge between me and the Stuttgart’s team. That is one of the most important results, because long term, challenging goals can be achieved just through commitment and mutual exchange of knowledge and experience.

We are writing a paper about the development of the topology manager shortly presented above. That would have not been possible without the important discussions and ideas had thanks to the visiting period in Stuttgart, made possible by PerAda.

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