SITUATED SPATIAL AWARENESS

Experimenting with spatial concepts for agents

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Abstract. The target of the project is to explore spatial awareness in situated agents. The concepts are tested with exhibition layout as use case and subsumption architecture as cognitive model. The agents in the implementation control the location and orientation of exhibits in a collaborative environment. The paper describes the implementation details and discusses the outcome.

1. Introduction

This ongoing project aims at implementing spatial awareness in situated agents. The concept is being tested using Croquet as collaborative environment and interactive exhibition layout as field of application. Thereby the agents are used as invisible vehicles for the exhibits, essentially controlling their location and orientation.

Spatial awareness, the concept of realizing your spatial situation relative to that of other entities and perhaps being able to infer how this relationship will change upon action can be seen as a step towards spatial reasoning. While this is a grand enough target in its own right, the need to represent and test functionalities called for a virtual-world problem as a case study. Exhibition layout was chosen as use case since it offers numerous spatial relationships which must be considered. First, there is the exhibit-to-exhibit relationship. Exhibits may not collide and the users view to another exhibit may not be obstructed. Second, one must consider the exhibit-to-user relationship. The exhibit must face the viewer while enabling sufficient distance or proximity to achieve the intended experience. Third, there is also a kind of exhibit-ensemble-to-user relationship which cannot simply be seen as an addition of the former two, but rather requires a second order awareness of relationships between other entities. Individual agents must sometimes agree to suboptimal positions for the benefit of the group.

2. Method

The work is intended not only for the virtual realm but rather should also allow reflection back into reality. Hence a use case was chosen which would be applicable to both. Since the emergence of virtual reality and the current rise of collaborative environments an increasing number of museums, galleries and other exhibitors have chosen to maintain branches within virtual reality. Thus exhibition layout seems to be a use case with a real need for spatial awareness in both virtual and real situations. Additionally, different environments pose different constraints such as gravity and the need for a carrier surface in the real world or navigational limits in virtual environments, hence the method must be flexible enough to accommodate varying requirements.

Situated agents, with a limited awareness of their surrounding, control the location and orientation of the exhibits. A subsumption architecture (Brooks 1986) forms the basis of the agent's behavior. This kind of rule-based hierarchy mainly operates as mapping from sensory inputs to effectory output, thus by-passing the need for elaborate internal models.

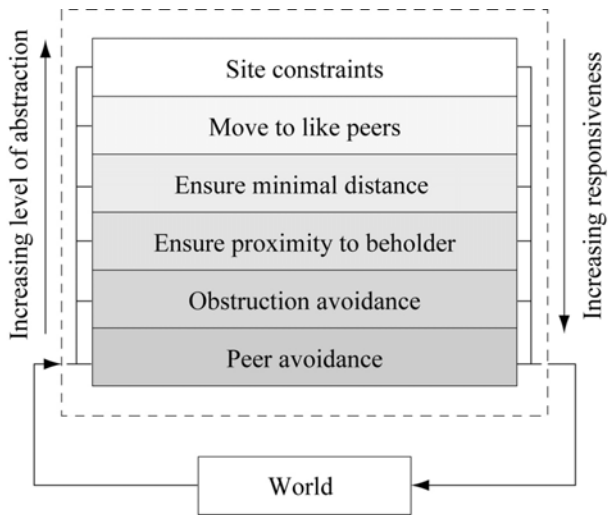

Figure *1:* The agents rule hierarchy; the lowest level behavior defaults to line of sight calculations; higher levels subsume and extend lower levels

The main inputs the agent can operate with are the relative positions of the other exhibits, user actions, agent communication, geometric site constraints, the overall layout concept as well as a popularity measure derived from user interaction with the individual exhibits. Thereby the user actions, the agent communication and the popularity measure are the only active elements and hence can serve as triggers for the agent's behavior. The relative positions, the site constraints, the layout concept and the popularity measure account for the environments current situation and hence can be seen as the agent's external memory. Once the agent's behavior is triggered all the above inputs are used to determine the appropriate reaction.

The agent's lowest level behavior is to check for collisions with other agents (Figure 1). The second level is concerned with various lines of sight, depending on the intended layout. This can be with respect to a single vantage point or a vantage line. In order to keep computation low and responsiveness high bounding sphere algorithms are used for these two steps. Future versions should implement more finely grained algorithms. The third and fourth levels are concerned with the exhibits distance to the viewer. The fifth level essentially implements a mechanism to group like exhibits according to some similarity measure. Finally, the top layer ensures that the geometric constraints imposed by the site are met.

2.1. ORIENTATED AWARE AGENTS

The awareness model implemented in the agents is based on Benfords (Benford and Fahlén 1993) work, which was originally intended to support interaction in multi-user environments. The agents are equipped with various awareness related properties such as aura radius, focus angle, focus radius as well as the nimbus direction (Figure 2a).

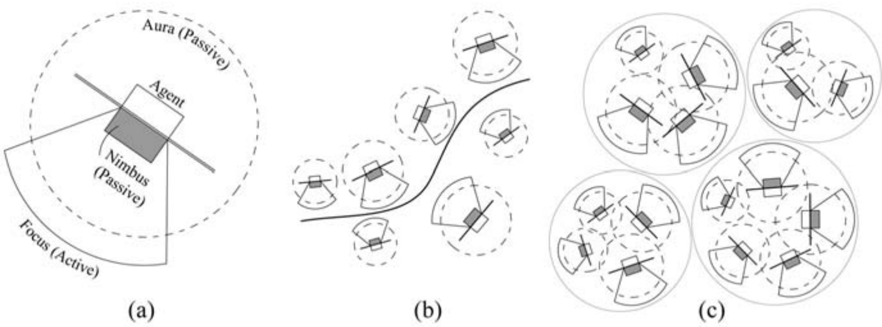

Figure 2. (a) An aware agent as described by Benford and Fahlén; (b) An example for an arrangement along a linear path; (c) An example for an open floor plan concept

Aura can be seen as the space within which other entities can become aware of ones presence. The visual aura differs from the auditory aura, which in turn hopefully differs from the olfactory aura, thus aura is medium specific. Focus describes the space which an agent is aware of. Nimbus on the other hand determines the degree of awareness evoked in another agent; the front side of a painting will usually cause more awareness than the back of the canvas. Additionally, the minimal distance between the beholder and the exhibit is available, more generally this measure can be interpreted as comfort distance or personal space.

2.2. ENVIRONMENT

The static information provided by the environment mainly comprises the expected user locations in form of paths or areas, the overall exhibition foot print and possibly a preferred layout concept such as linear or open (Figure 2b-c).

Virtual exhibitions have more freedom to populate the environment in all dimensions, real world layouts must of course adhere to the laws of gravity and thus representations for walls and levels must be implemented.

2.3. POSITIONAL BEHAVIOR

The main task the agents must achieve is to find a position which enables the viewers an optimal view of the exhibits. This includes maintaining an acceptable distance, neither too near nor too distant, and verifying that the observers view is not obstructed by other exhibits.

The behavior is implemented using a subsumption architecture as described by Brooks (Brooks 1986), thereby more vital lower level behavior takes precedence over higher level behaviors. Essentially this means that as long as the more basic constraints, such as not colliding with other objects, are not fulfilled the more abstract ones, such as maintaining an acceptable distance, aren't even tested. Hence the order in which the behaviors are activated strongly influences the outcome of the cycle.

2.3.1. Find expected vantage point

For many of the following calculations it is indispensable that the agent has an expected vantage point, a point towards which it can present itself.

Currently this defaults to the nearest point on the path or of the area where the user is expected to be. A more sophisticated, albeit computationally more expensive, measure is to maximize the number of points from which acceptable views are achieved, not to simply optimize the experience for a single vantage point.

2.3.2. Collision avoidance

This most basic behavior ensures physical integrity between the agents. It is based on bounding sphere algorithms. Once additional objects such as building elements or furniture are introduced they will be included in the collision detection cycle.

2.3.3. Obstruction avoidance

The second level aims at positioning the agents in such a way that the view from the nearest point to the exhibit is un-obstructed. In essence, for each object in the agents focus a fictional shadow cone extending from the expected vantage point and circumscribing the objects bounding sphere is calculated, If the agent does not collide with these fictional volumes, an unobstructed view from the vantage point is guaranteed.

2.3.4. Include vantage point in aura

In order for the beholder to appreciate the exhibit, he must first become aware of it. The agent tries to support this process by positioning the expected vantage point within its aura; additionally as will be described later the effect is maximized by correctly orientating the nimbus towards the beholder.

2.3.5. Exclude vantage point from minimal distance

An exhibit may also provide a minimal distance; this behavior ensures that the expected vantage point does not lie within this sphere. As mentioned earlier the minimal distance can be seen as the minimal distance required for comfortable viewing in the case of an exhibit or as personal space in the case of an agent.

2.3.6. Move to like peers

Finally, in order to provide for a certain amount of grouping of like exhibits the agents tend to move towards other agents of the same category. Currently discrete categories are attributed to the agents, more continuous measures may provide for higher flexibility.

2.4. DIRECTIONAL BEHAVIOR

Apart from being positioned correctly it is of course vital that the exhibit is presented from its most advantageous view. Within the Benford-model of awareness this means that the nimbus must be orientated towards the onlooker.

2.4.1. Orientate towards point

A separate branch in the subsumption architecture is reserved for directionality. Currently this involves rotating the agent so the beholders view is normal to the nimbus plane. In order to expand the expected vantage point to a line or an area it will be necessary to implement a more generous understanding of an acceptable viewing angle.

3. Application

Croquet, an open source program for the creation of multi-user collaborative virtual environments, was chosen as implementation platform. Based on the educational platform Squeak it is ideal for collaborative, proof-of-concept implementations (Grasl et al. 2006). For simplicity most behaviors are based on bounding sphere algorithms, however the system is extendible, should a higher degree of accuracy be required the respective operations can be overridden by augmented calculations.

In the test environment the agents are rendered as simple cubes with a surrounding, square halo indicating size and directionality (Figure 3). The bright side of the halo corresponds to the front side; the more bright area is visible the higher the awareness based on the objects nimbus. The darker side of the halo indicates the back side. Additionally the cube's color visually represents the respective agent's category.

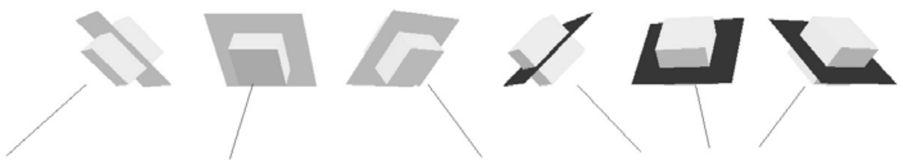

Figure 3. The orientated agent is rendered as cube with a simple halo indicating directionality

When viewing the scene from the expected vantage point (Figure 4) it may seem as though the exhibits are partially overlapping. This is however due to the fact that the bounding spheres where inscribed into the exhibits, rather than circumscribed in order to achieve a denser layout.

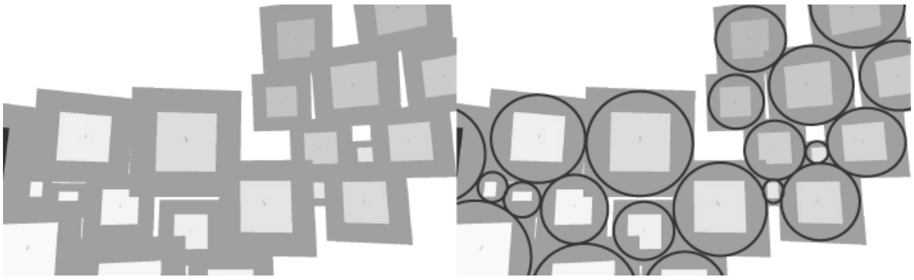

Figure 4. The overlap as seen from the expected vantage point is due to the chosen bounding sphere approach. In this example all agents are orientated towards a single point.

3.1. DISCUSSION

While most agents find a reasonable position to present themselves and fulfill most of the requirements, some of agents located in the third or fourth row have difficulties satisfying the distance constraints in accordance with the visibility constraint (Figure 5). The agents are caught in a continuous cycle of moving away from the vantage point in order to be seen fully and re-approaching the vantage point to bring it within its aura. To resolve this issue the agent must either communicate its dilemma to the other agents, asking for support, or by simply jumping to the front of the group, forcing the other agents to make room.

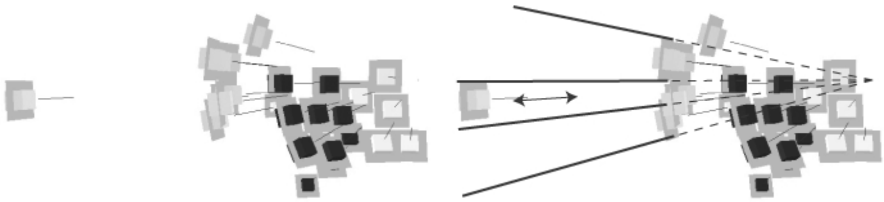

Figure 5. The agent can get stuck in a funnel between obstruction cones while trying to find the correct distance. A mechanism to break this loop must be implemented.

It has been interesting to see how well the agent's behavior can be modeled using a subsumption architecture and although the target behavior was implemented successfully it is lastly an emergent behavior and the level of awareness allowed by the strict interpretation of the situated action paradigm is relatively low.

Some kind of second order reasoning, based upon an internal world, must be introduced into the situated agent, similar to Geros situated FBS (Gero and Kannengiesser 2004). This will enable more sophisticated inferences and constitute an important step towards spatial cognition.

4. Future Work

Future versions must include more sophisticated means of optimizing possible attention. The point of interest should not simply default to the nearest point but rather the segment of the path within the agent's aura must be maximized.

The popularity measure has not been implemented yet; this would create an additional mean of resolving conflicts between rivaling agents by introducing a hierarchy. A higher order agent could then command another agent to move instead of having to shift himself.

Currently mainly virtual exhibitions are served by the application; there is no sense of gravity, of acceptable vertical viewing angles and no means to import existing gallery footprints.

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