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IKeWYSe – I Know What You See

An educational ontology-driven simulation game to foster perspective-taking skills

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Abstract— This work represents the evolution for educational purposes of a video game designed for the measurement of perspective taking skills. The prototype of the game from which this study started has been developed by the University of Salerno and is aimed at assessing the age at which students develop perspective-taking and mental rotation skills. The shift from the scope of measurement to that of training required the software to be capable to adaptively suggest effective strategies appropriate to the user's profile. Notwithstanding the theoretical framework and the approach to the representation of spatial reference systems, the specific educational needs have led to a complete re-design of the application and to the introduction of a semantic layer that can adaptively support user. This paper, therefore, in the first part presents the theoretical framework behind the project and briefly describes the prototype of the game aimed at measuring the perspective taking skills, and, in the second part, presents the design of a specific ontology for the educational version.

Keywords— Empathy, Spatial reference frames, Learning, Avatar, Perspective Taking.

I. THE CHILD'S CONCEPTION OF SPACE

Jean Piaget argued, within the theory of spatial thinking development stages, that the child is able to imagine different views from his own no earlier than seven or eight years of age; in other words, about seven / eight years of age the child acquires the ability to manipulate spatial points of view.

The original ideas of Piaget on mental development have focused on egocentrism in early childhood, on the basis of experimental studies, such as the famous three mountains problem [1]. In the three mountains test, a child must indicate the point of view of an observer who is in a different location.

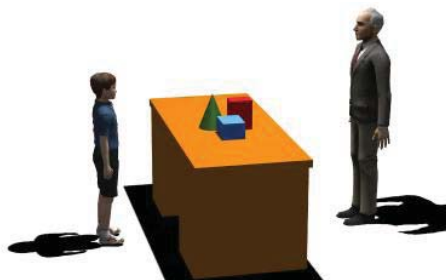


Figure 1 – The three mountains problem



Figure 2 – Piaget's view



Figure 3 – The child's view

Using this paradigm, children up to 7 years, do not seem to have the ability to assess a point of view other than their own.

Only when the children reach the stage of concrete operations, between 7 and 12 years of age, they acquire the ability to "decentralization". This allows them to take into account multiple aspects of a task to solve it. According to Piaget, egocentrism, defined as inability to decentralize and to take the perspective of another person, is the norm in young children. The terminology of Piaget has a direct relationship with the study of spatial reference systems.

While navigating in space, in fact, visual, vestibular proprioceptive and motor information are combined to extract spatial invariants and to draw a representation of the environment. A key concept in the field of spatial processing regards the definition of the reference systems used by the central nervous system to interpret the sensory information and to locate objects in space.

II. REFERENCE FRAMES

With the words "reference systems" we refer here to coordinate systems through which the central nervous system encodes the relative positions of objects in space, including that of the body itself [2].

In other words, a reference system is a way of representing the positions of the subjects / objects in space.

The spatial position of an object can be represented in the brain with respect to different classes of reference points, which can be related or not to the position of the subject.

In a nutshell, we can say that there are two types of transformations of space imagery: the allocentric spatial transformations, that involve an object-to-object representation system and encode information about the location of an object or its parts in relation to other objects, and the egocentric spatial transformations that involve a subject-object representation system.

In the allocentric reference system, the information on the position of an object is encoded according to the position of other objects. The position of an object is relative to the position of other objects.

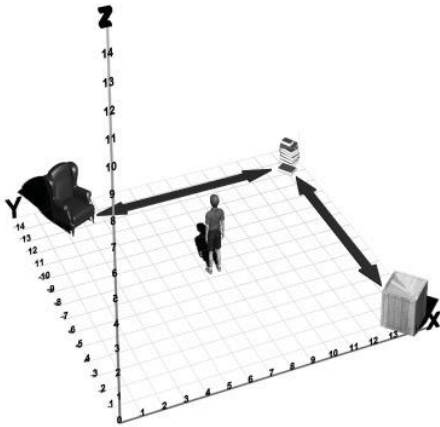


Figure 4 – Allocentric reference system

In the egocentric reference system, the information on the position of an object is encoded according to the body axes of the subject. The position of an object is relative to the position of the subject.

Allocentric and egocentric spatial representations significantly differ. The spatial information provided by an allocentric representation are referred to a space external to the perceiver; the information provided by an egocentric representation refers to a person who perceives with a defined orientation axis.

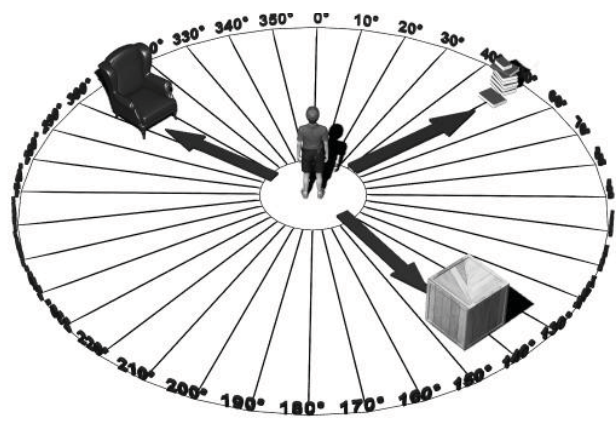


Figure 5 – Egocentric reference system

In particular, the allocentric representation encodes the positions of points in space in the internal equivalent of a system of Cartesian or polar coordinates. The egocentric representation uses a special polar coordinate system whose origin is the ego (the perceiving subject) and the reference axis is the axis of orientation of the subject, by encoding the position of a point in terms of distance and angle from the subject.

III. SPATIAL THEORY OF EMPATHY

Piaget's theory on egocentrism has sparked a lively debate of which Perner provides a comprehensive overview [3]. Rochat has shown that children of 3 years of age are able to discriminate what they can reach directly from what instead is reachable by someone else. The conclusion of Rochat is clear: since the age of three years, the children can take the perspective of others, and are capable of spatial decentralization and flexibility in the spatial reference systems depending on the operation to be performed [4].

Martin Hughes [5] argued that the three mountains task did not make sense to the children and was made more difficult because the children had to match the doll's view with a photograph.

Hughes "devised a task which made sense to the child. He showed children a model comprising two intersecting walls, a 'boy' doll and a 'policeman' doll. He then placed the policeman doll in various positions and asked the child to hide the boy doll from the policeman"[...]

Hughes showed "that children have largely lost their egocentric thinking by four years of age, because they are able to take the view of another"[5].

The point that seems particularly interesting for the purposes of this work is not the disagreement between Piaget and post-piagetian researchers about the age at which a child can take the perspective of others. Beyond the age parameter, all researchers share the same approach to the definition of "allocentric" and "egocentric". The task of the three mountains

requires to take the visuospatial perspective of another person. This perspective, albeit about a different subject, it is still an egocentric perspective. The three mountains task, according to Frith and de Vignemont, is always based on an egocentric representation of the object and cannot inform on the ability about taking an allocentric perspective by young children [6].

This seems to be in agreement with the view of the Vogeley and Fink, according to which "the difference between first and third-person perspective is that 3PP (Third Person Camera) necessitates a translocation of the egocentric viewpoint" [7].

The ability to assume an allocentric perspective, however, is not reducible to the mechanical assumption of the position of other persons in the space. The central node is the possibility to make a "mental rotation, in relation to the environment or to an object in the environment, while maintaining a main perspective of the environment in question" [8].

Basically, it is to be both yourself and the other. Precisely this is the key feature, for Alain Berthoz, of empathy: empathy is a dynamic process that requires a doubling. It is, in short, to adopt an egocentric point of view, but after an allocentric manipulation, while inhibiting the emotional contagion, which is rather typical of sympathy.

In the words of Berthoz,

"Si je vois quelqu'un ayant eu un accident de vélo et qui souffre, il ne faut pas, si je veux l'aider, que je me mette à souffrir, ce n'est pas très utile" [9].

The spatial manipulation, in this framework, it is one of the cornerstones of the concept of empathy.

Alain Berthoz proposed a spatial theory of empathy, based on the human ability to intervene on the management of the point of view. According to Berthoz, "empathy is important for social relation and to guess the opinions of others. Finally, it is essential to rational thinking, because it allows to examine the facts and arguments from different points of view. This mental operation assumes that you accomplish a sort of mental rotation on themselves, in relation to the environment, or an object environment, maintaining a main perspective environment in question" [8].

The reflection of to Berthoz, gained in studies of *Physiologie du changement de point de vue* [9] is a continuation of the phenomenological tradition:

"In relation to a modern conception of the philosophical tradition of phenomenology and a primary role of cognitive Embodiment" Berthoz showed "that there is a basic difference between sympathy and empathy. While sympathy is akin to an emotional contagion and does not require the subject to adopt the point of view of others, empathy requires a dynamic and complex manipulation of spatial reference systems" [10].

In fact, this approach represents a reversal with respect to neuroscientific perspective that "addressed the question of the neural basis of sympathy and emotion via emotional contagion and resonance and do not address the complex dynamic mechanisms of empathy" [10].

In the hypothesis developed at the Collège de France, four processes underlying the empathic relationships were identified:

1. The construction of a coherent perception of our body and its relationship with the environment.

2. The ability to resonate with the emotions and perceptions of others.

3. The ability to change the point of view or perspective and move our body and our brain in the body and in the brain of others ("Einführung").

4. The ability to abandon the egocentric perspective in order to adopt an allocentric perspective, inhibiting the emotional contagion [10].

Fully, Berthoz hypothesis is that these processes require the contribution (albeit not exclusive) of different brain mechanisms involved in spatial perception, in mental manipulation of the reference systems and in perspective change.

The Problem of Empathy, however, is not reducible to spatial information management and taking the mechanical of the position of others in the space. The central node is being at the same time ourselves and the other, through a change of perspective and a form of extra-body experience that separates us from our bodies and navigates the bodies of others through our "second self" or "mental double"[11]or "doppelgänger [12].

Empathy, then, is not simply reducible to the mirror neuron system, does not affect the ability to simulate the action, or the experience or the emotion of others, but it concerns the ability to change the point of view while remaining ourselves.

IV. A VIDEOGAME FOR THE MEASUREMENT OF PERSPECTIVE TAKING SKILLS

On the basis of the «*three mountains problem*» and the subsequent scientific debate about the age at which the child acquires the skill of perspective taking, in a previous work we have designed and developed a video game aimed at measuring the ability of perspective taking.

The game prototype requires the user to navigate in three-dimensional space through an avatar.

The player's default view is a semi-subjective view, with the avatar seen from behind.

The player addresses three different tasks of increasing difficulty.

The first two tasks are complementary and have the purpose of measuring the perspective taking skills, the third task has the objective of measuring mental rotation skills.



Figure 6 – a game screenshot

A. First Task

In the first task, the player's avatar is in a park, and has in front of him two people. A window shows the point of view of one of these people. The player's task is to click on the person whose point of view is shown in the top window.

The player can select different points of view by pressing a key on the keyboard, switching from semi-subjective to subjective view, and from subjective to top-down (objective) view.

To access the next task, the player must provide five consecutive correct answers.

B. Second Task

In the second task, the player has in front of him only one person. Two windows in the upper screen show two points of view, the one of the person in the park, and a fake one. The player's task is to click on the window showing the point of view of the person in the park.

C. Third Task

In the third task, the user is struggling with an invisible man. The player cannot see the man in the park, but can see, in the top window, what the man in the park is seeing. The area of the park has been divided into six zones. By moving the mouse, the user can select the area of the park in which he believes to be the man whose perspective is shown in the top window.

The current stage of development of the game and the related experiments are described in [13] and [14].

V. FROM MEASUREMENT TO TEACHING

The created prototype was focused to check the empathy of children but not to train their empathy skills. In this work we propose to extend the prototype in order to train students and improve their empathy skills.

In the original video game prototype, tasks are ordered by increasing difficulty. To avoid bias due to the memory of the scene, the location of objects and characters are assigned randomly for each attempt. The number of attempts that a user has available for each task varies individually: the task is repeated until the user learning curve stabilizes. The measurement takes into account the relationship between successful attempts / total number of attempts. No hint is provided to user.

The nature of an educational product has obviously different characteristics: for each task, when the user supplies an incorrect solution, the software can not simply continue, indicating the correct solution, but it must provide the user with an explanation of the reason why his choice is not correct, and it must indicate the correct choice, supporting adaptively the user with a series of individualized suggestions.

To do so, we propose to create an ontology framework that is able to describe a scene and to infer what facts are true for each possible egocentric point of view of the scene and the reason of its truthiness. The proposed system should be able to:

- Give clues to students when they need help: suppose the student is playing in the first task and does not know what scene to choose. If she asks for help, then the system must be able to say things like: "When identifying the perspective of another person you have to think what elements this person has in its right and in its left. For example, that tree that is in your right is on the left of person 1 and on the right of person 2. If the point of view would be the one of person 1, where do you think the three should appear?"
- Support students when they choose incorrectly: suppose that a student is playing the first task and choose the wrong person. Then the system should be able to say something similar to "Are you sure this person is the one that has that point of view. If so, you will appear in the right of the scene and not in the left because you are in the right of this person."

The ontological framework will be the tool used to provide interaction in the system, guiding the students to the correct solution with incremental pieces of information and rationalizing why the decisions taken by students are right or wrong.

VI. ONTOLOGICAL FRAMEWORK

The ontological framework proposed should represent information about the tridimensional scenes of the game, including the position of each element within the scene from an allocentric perspective, provide a set of rules to infer what is the egocentric position of the scene elements in arbitrary points of view and construct some sentences that explain why the elements of the scene are placed in their position from such egocentric perspective. Therefore, the information the ontological framework should contain are:

- Geographical information from the scene: shape, bounds, elements contained, position and possible

points of view: in this first version we will simplify the ontology to represent only a two-dimension version of the scene, which is enough for our requirements.

- A set of rules to create an egocentric perspective of an scene for the defined points of view.
- A set of rules to give clues about how the elements are placed from an egocentric perspective,
- A set of rules that explain why the elements are placed in a given place from an egocentric perspective.

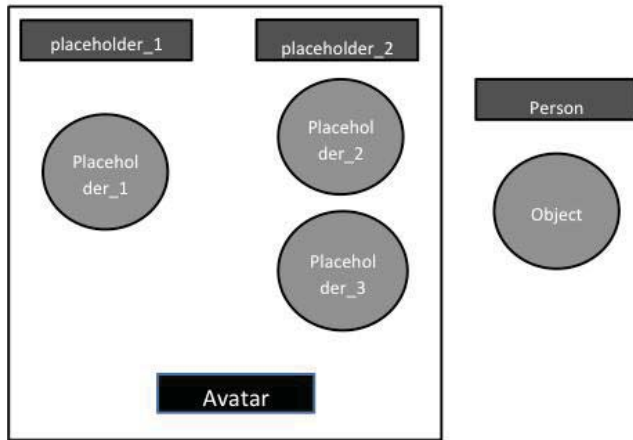


Figure 5 – layout and distribution of the scene.

In order to simplify the game, the kind of scenes that are used in the game follows a certain pattern presented in figure 5. All scenes may have 3 objects and 3 people. The objects and the people may be different, but their ubication is always the same. Figure 5 shows the location of the people in the scene (represented by rectangular shapes); the position of the avatar the other two people is fixed. The figure also shows the possible placeholders of the objects in the scene. The kind of objects that can appear in the scene are trees, bank benches and streetlights.

The possible points of views of the scene are 5, one for each person that is within the scene (the camera position coincides with the position of the person’s eyes), one that follows the avatar at a fixed distance from behind, and an orbit camera for top-down views. Last two cameras are created in order to improve the usability and the beauty of the game.

Figure 6 shows the ontology that has been created for specifying the geography information of scenes. The main classes are *Scene* and *PlaceHolder*, which respectively represent the scene and the placeholders. A relation about the two classes called *elementsInTheScene* represents the elements that are placed within the scene. In our case its cardinality in the *PlaceHolder* side is 6 since only 6 elements are allowed in scenes. The position of the elements in the scene will be defined by the *PlaceHolder* class.

According to the kind of element, *PlaceHolder* may be specialized in human and object (*HumanPlaceHolder* and

ObjectPlaceHolder). *HumanPlaceHolder* allows representing the people in the scene, which can be in our case the Avatar and non player characters. For each person, we want to know what is the direction he/she is looking at, which is represented in the ontology in the attribute *directionWherePersonsLooking*. The value of such attribute is an angle that represents where the person is looking at. Since the direction where the human elements are looking is fixed in the game, the value of this attribute has been automatically setted to 90 and 270 degrees in the classes *Avatar* and *NonPlayableCharacter*.

An object may hide other objects behind it according to the size, shape and density of both objects. Therefore, such characteristics should be taken into account for *ObjectPlaceHolder* instances. However, in this preliminary stage, we will simplify such process and just use an attribute in *ObjectPlaceHolder* that determines whether the object can hide other objects. Such simplification can be done due to the simplicity of the scenes and the type of objects we use. In particular, only tree objects can hide the objects that are behind, so we will only have into account this for trees. The *ObjectPlaceHolder* class has also been specialized to indicate the different objects that the scene can contain (streetlights, bank benches and trees).

Note that the classes *PlaceHolder*, *HumanPlaceHolder* and *ObjectPlaceHolder* are abstract since the only possible instances come from their subclasses. The ontology has also another integrity constraint that has not been drawn in the diagram that determines the distribution of how many object placeholders are (3) and how many person placeholders are (1 avatar and 2 NPC).

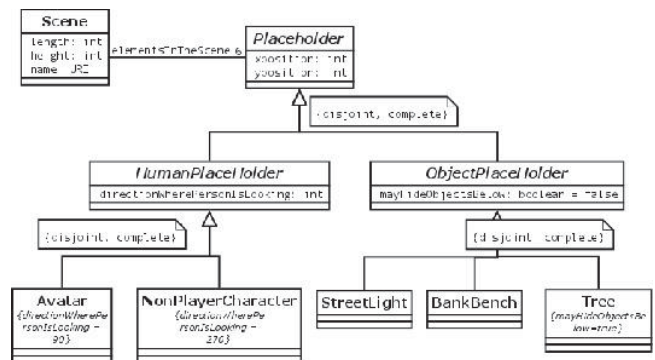


Figure 6 – UML Diagram of the designed ontology.

The design of the presented ontology is the first step to be able to give clues to players and rationale their elections in the game. Once the scenes are represented as instances of the ontology they would be able to be queried to infer clues and explanations.

Due to the simplicity in the definition of scenes, in this prototype we will not use sophisticated techniques to find out the different egocentric perspectives. We will do it conceptually, by very simple rules, and attack this problem in

the future, as we extend the different scenes to be taken into account in the game.

In this first version of the prototype we have defined a set of simple rules to find out what elements should be seen in each egocentric perspective and what are the relationships between them. These rules will allow to detect, for each egocentric perspective, what are the elements on the right, on the left and what are the closer elements. For example, the rule that checks whether if a element $e1$ is closer than another element $e2$ from a human perspective p are the following.

-- Returns true when $e1$ is closer that $e2$ from p perspective.

closer($e1:ObjectPlaceHolder, e2: ObjectPlaceHolder, p: HumanPlaceholder$):-
 $(p.isTypeOf(Avatar) AND e1.y < e2.y) OR$
 $(p.isTypeOf(NonPlayerCharacter) AND e1.y > e2.y)$

Note that the rule should take into account that the direction of looking of avatar and NPC are different.

These rules can be used to give clues and explanations to users. For example, we can use the closer rule to explain why the distance of elements $e1$ and $e2$ and different in two different perspectives.

$if(closer(e1, e2, p1) AND closer(e2, e1, p2)$
 $AND p1.isTypeOf(Avatar)) \rightarrow$
 Say to student

“Note that your perspective and the one of the chosen character are very different. The object” + $e1$ + “is closer than” + $e2$ + “to you, but it is the contrary for the other person. Do you know Why? Turn the camera to see the scene from the top and try to find the reason.”

VII. CONCLUSION

This work is based on a previous project whose goal was the design of a video game aimed at the measurement of the player's perspective taking skills. The purpose of this project is the design of a software aimed at training of perspective taking skills in the process of teaching and learning.

The ability to change the point of view is of great importance from the cognitive point of view: if, during the critical period in which a "window" for this faculty opens, this faculty is not acquired, once the "window" is closed, the child will remain locked in an unique view of the others [15].

“There is general consensus among theorists that the ability to adopt and entertain the psychological perspective of others has a number of important consequences, including empathic concern” [16].

The shift from the scope of measurement to that of training required the software to be capable to adaptively suggest effective strategies appropriate to the user's profile.

As part of the ongoing research, the extension of previously existing game prototype has been designed through the introduction of a semantic layer aimed at the automatic construction of the scenes and at the definition of feedback and adaptive prompts in relation to space and user actions.

On this basis, this research is defining an ontology framework that is able to describe a scene and to infer what facts are true for each possible egocentric point of view of the scene and the reason of its truthiness.

VIII. REFERENCES

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