Understanding The User Interfaces Through Spatial Metaphors

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Abstract. This study focuses on spatial metaphors in digital interfaces that designers use in their modeling processes. When designers themselves perform an action by using a digital tool, they often make spatial inferences without realizing it, with the help of their mental models and established modeling experiences. In order to trace these implicit spatial metaphors, the spatial metaphors used by the designers were discussed through their verbal expressions. Within the scope of the pilot case study, the participants told each other the 3D models given to them verbally, and the other participant made the 3D model simultaneously with the narrative. The metaphors that the participant in the role of the narrator used with the intention of making a spatial description allowed the participant in the role of the modeler to build spatial relations. This study, which has the potential to provide a spatial framework for interfaces in the future, is a step toward designing new user interface metaphors.

Keywords: Spatial metaphors, User interface, UI metaphors, Modeling process, Human-computer interaction

1 Metaphors in User Interfaces

Metaphors, which are frequently the subject of research in the context of HCI, enable people to transfer the knowledge and experiences they are familiar with from the physical world to user interfaces (Hoshi et al., 2011). Metaphors that establish an intuitive and logical connection between what UI components represent in the digital world and real-world concepts make it easier for users to understand and interact with the interface. The use of metaphors for the concepts already in the mind of the user in interfaces, on the other hand, reduces the mental load (Wang & Huang, 2000) and enables more natural communication with computers. When using an interface, the user wants to remember a function and focus directly on the task they want to perform, with minimal cognitive effort (Ark et al, 1998). The experience in the program used allows the user to use it without even reading the names of the elements in the interface (Kaptelinin, 1993). In this sense, it is possible to say that users also have a spatial area within the UI and the relationship between UI components is formed according to this spatial framework.

Fineman (2004), who makes use of direct manipulation, manipulation, and human interaction while explaining the relationship between HCI and metaphor, strengthens his argument through the example of email. Direct manipulation is based on the ability to perform metaphorical actions such as moving, dragging, and compressing an email like a physical mail. Navigation refers to the use of metaphors such as the ability of users to search, navigate, and go back and forth between emails. Human interaction, on the other hand, refers to the user's ability to request help, approve, and give commands from the interface. The metaphors used in this communication between the interface and the user also allow the user to establish spatial relationships by making use of the information of the physical world.

Lakoff and Johnson (1980), stating that spatial metaphors regulate many concepts in human cognition, mention that almost all conceptual metaphors are related to the projection of space and the human body. Understanding abstract spaces shaped through spatial metaphors is an important part and supporter of UI. Spatial UI metaphors create a mental mapping between the real world and the digital world. The purpose of this mapping is to create a more intuitive and natural interaction between the user and the digital environment.

In the real world, the network of perceived items and relationships against a physical environment is similarly questioned in the digital environment. The designers use the navigation tools in the UI to perceive the objects they see in the digital environment in 3D as in the real world. Maps, orbital movements, or navigation bars support the spatial perception of design representations. In a 3D environment, spatial navigation employs techniques such as moving forward, backward, up, down, or left, right as well as turning or rotating in different directions to allow the user to move around and explore the space, and interact with the virtual objects within it. Designers can use visual cues, such as perspective and depth, to create a sense of spatial relations between different design elements in the UI. Spatial navigation techniques such as scrolling, panning, and zooming allow the user to move around and explore the interface. The UI allows designers to be in digital space using different approaches, directly manipulating the objects, navigating among them, and interacting with their environment.

The spatial metaphors discussed in this study are evaluated in the context of UI in a case study. It is aimed to gain insight into the implicit spatial metaphors that designers use in their interactions with the interface during the design process. For this reason, instead of the process in which the designers modeled directly, the narratives in which they had someone else do this modeling were discussed. Designers in the roles of narrator and modeler evaluated objects and relations between objects in the digital environment according to their own spatial expressions.

2 Representing Spatial Information Through Metaphors

Space, being at the center of perception and cognition, enables the human mind to organize actions in a specific spatial order (Kuhn & Blumenthal, 1996). This perception formed in the mind gains meaning in relation to the metaphors that shape the representation of beings (Gärdenfors, 1996). Although representations are a powerful concretization tool for the abstract idea in the mind, they need a spatial domain.

Spatial information is formed by the complementary representation of objects and relations between objects. While translations such as rotation and manipulation can be made on objects in space, the relative positions of objects and relations between objects support navigation in space (Newcombe et al., 2013). These objects represented in space also give information about space apart from the object, and the spatial information in the mind also changes with the differentiation of representations. The reference created in the mind continues to create new spatial representations in line with manipulation, and navigation.

Spatial representations based on inter-object relations that convey environmental information and contain spatial information from different formats can be expressed in many different formats. Bennett (2008) mentions six concepts for spatial representations: 1. The basic Euclidean forms represented by points, lines, and regions are the most primitive building blocks and new representations can be created with different combinations of these geometric elements. 2. Mereological approaches in which spatial relations such as overlap, and separation are at the forefront. 3. Topological relations refer to the connections between the object and the environment (Bennett, 2008). 4. The concept of in-between is closely related to the positions of objects in space. 5. Regarding aspects, north, south, east, and west, which is the most widely used allocentric spatial description according to Tversky (2019), is an approach that refers to the real world since it is not directly related to the body. 6. Finally, spatial information can be expressed with the metric approach with the Cartesian system. In this sense, the use of the Cartesian system is at the forefront of the most powerful ideas of visualization for visual representations in the digital environment (Averbukh, 2019). All these approaches play an important externalizing role to create spatial relationships that can be expressed from object to space, from mind to representation. The metaphorical discourses used also change according to the approach in which spatial knowledge is expressed. Metaphorical discourses such as the fact that a line is tangent to a circle intersect with another line, or that the distance between two points is X units from the zero point gives information about both spatial relations and representation in space.

3 Spatial Metaphors According to Egocentric and Allocentric Approaches

Lakoff and Johnson (1980) mention spatial metaphors based on orientations such as up-down, front-back, in-out, or central-peripheral are formed according to the human body and its relationship with its environment. In spatial metaphors, space is based on the appearance of an entity (Kuhn and Blumenthal, 1996), and one's perception of the physical world through the spatial framework of one's own physical being. The spatial framework is based on the perception and interaction between people and their environment (Bryant et al, 1992). Reference frameworks that make it possible to locate an object in space are based on the relationship between the object and the observer. When the body is considered in the center, the functions of the space around the body and the area where the body navigates are different from each other, therefore their conceptualizations are also different (Tversky, 1998; Tversky, 2005).

According to the spatial framework, the space of the observer consists of three dimensions, one vertical and two horizontals, and this vertical axis is also positioned relative to the axis of the body (Tversky, 1991; Bryant et al, 1992; Tversky, 1993).

The presence of the body in the egocentric approach creates a relative state between the observer and the object, and the egocentric reference frame changes accordingly. In the egocentric approach, in relation to the relative relationship between the observer and the object, the egocentric direction is defined according to an internal orientation axis of the observer (Klatzky, 1998). It is important that the egocentric expressions used when guiding someone else or telling where an object is, have a certain equivalent on the opposite side and that this correspondence is valid so that spatial information can be transferred correctly. In the center of the routes expressed along the extensions in line with the axes of the body, there is 'me' and the main decisive question in a narrative involving two people is 'according to your perspective or my perspective?' (Tversky, 2019). Depending on the answer to this question, the spatial setup of the correspondent that the narrative reaches also changes and organizes its space according to its own body or by adopting an allocentric approach.

In the allocentric case, the reference frame is external to the individual, and other signs and relationships in the environment are followed, regardless of the individual point of view. Being able to construct complex spatial relationships by creating a mental representation even in spaces that have no place in memory is fed by this allocentric approach. In the allocentric approach, the object represented has an origin and a reference direction. The reference is independent of the observer and depends on the relations between objects and their spatial positions (Klatzky, 1998; Moraresku and Vlcek, 2020).

The reference framework in the physical world is expressed in different representational dimensions in the digital world, and accordingly, its corresponding perceptions in the mind also change. It allows to perceive reference frames in the digital world at different scales and perspectives. Spatial clues provided by technical terms such as up-down, in front-behind, right angle, or vertical plane help to construct the space (Talmy, 1983) and provide new references that enable spatial relations to be fictionalized in the digital environment.

4 Methodology

Within the scope of this research, the implicit relationship of spatial narratives to their counterparts in the user interface has been examined through the processes of two designers making a model for each other by creating instructions. Simultaneous modeling of the verbal narrative will provide insight into the unfolding processes of possible spatial metaphors that can be used.

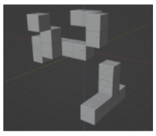
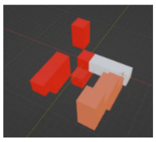
Two experienced architect participants took part in the test conducted. Both have modeling experience professionally in Blender for over four years. In the study, sessions were carried out considering the time constraint. Since it is worked as a pair, each sub-task for two people is planned to take 15 minutes and it is aimed to complete all tests in a maximum of 30 minutes. In the tests conducted face-to-face and in the same room, both screen recordings and video recordings of the participants were taken while they were working on the computer.

Within the scope of this pilot study, task distribution was conducted in an order. Firstly, participant P1 was the narrator and participant P2 was the modeler. P1 was given a model through SketchUp program and was asked to explain this model step by step. The P2 will simultaneously model this model in the Blender program. A maximum of 15 minutes was given for the explanation and modeling to be finished. Afterwards, narrator and models were replaced within the scope of Scenario A. A different model was described by P2 and simultaneously modeled by P1 on the Blender platform.

In the face-to-face study, each participant did a trial for about 3 minutes and decided how to tell. Then, with a maximum of 15 minutes, the actual simultaneous expression-modeling test was started. Since the modeling program in front of the narrator and the modeling program in front of the modeler are different, the narrator has included the interface functions of the tool used by the other party, relying only on its own experience.

By explaining the given reference models to their pairs, the participants, who made them make models through these expressions, both discovered the mass relations and virtual space in the interface and simultaneously explained it to the other party. The experience of the participants, both of whom are professionally involved in modeling studies, has changed the way metaphors are used in the narrative process.

Table 1. Overview of the pilot study (F: female, M: male). Source: Authors, 2023**.**

Narrator	Modeller	Narrating Duration	Narrating Environment	Modelling Tool	Knowledge of the Tool	Visual Output
P1 (F)	P2 (M)	11 min	SketchUp	Blender	+4 years	
P2 (M)	P1 (F)	9 min	SketchUp	Blender	+4 years	

4.1 Findings

In the process of their narrations, both participants determined a reference point (origin) for themselves in the model and derived other cubes starting from the cube at this point (Figure 1). The paths followed during the narration also affected the expressions, metaphors, and even gestures used in the narration (Figure 1). P1 described the spatial structure between the cubes, giving only references to the coordinate system during her narration. P2, on the other hand, occasionally used spatial metaphors such as *above, below, to the right,* or *to the left of the cube*.

P1 used a narrative and body language that gave the impression that she made the model herself during the narration period (Figure 2). She used first singular and plural expressions such as *'I am doing, we are deleting, I am moving'*. The gestures she made with her hands were mostly directed toward the objects on the screen. Since the Blender interface was not open in front of her, she tried to remember the shortcuts from time to time by placing her hands on the keyboard and imagining which keys she pressed. While transferring actions such as *'click on'* to the modeler, she also sometimes repeated the same actions with the mouse.

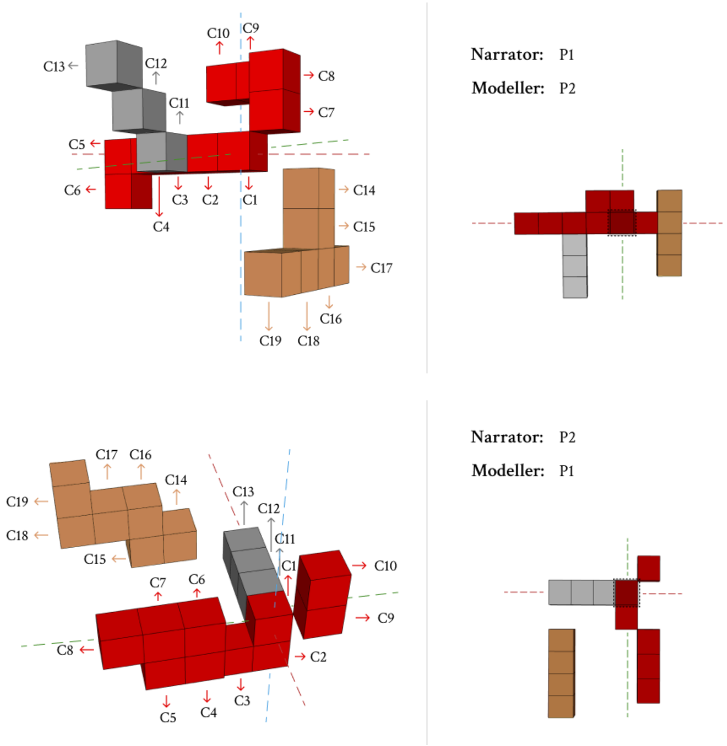


Figure 1. The projections of the sequence on the cubes followed by the participants in the process of their narration (red lines: X axis, green lines: Y axis, blue lines: Z axis, bordered area is the starting point). Source: Authors, 2023**.**

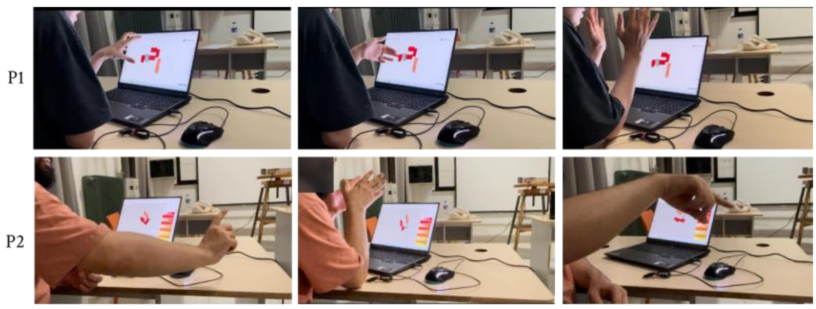


Figure 2. Gestures of participants when describing spatial relationships in the interface. Source: Authors, 2023.

P2 used expressions such as *'you are doing, you will add, move them'* and directly addressed the modeler. His gestures are facing the modeler sitting next to him, and he used finger points and gestures to support the digital spatial position of the cubes. Except for the basic shortcuts, he mostly directed the modeler by pointing out the functions in the interface. He specifically described these interface toolsets with their location in the interface and proceeded by getting confirmations from the modeler whether she found them or not.

Table 2. Metaphorical expressions according to spatial intentions in the context of metaphor and HCI relationship. Source: Authors, 2023**.**

Participant	Metaphoric Expressions	Spatial Intention
P1	We will *add* one cube	Direct Manipulation
	I could have *pushed them* by copying, I always *created* cubes	
	I'm *copying* my cube	
	I want to *make* the last three cubes I made *in this gray color*	
P2	We *select* everything on the screen	
	These cubes will *be in contact with* each other	
	Select the last cube we created	
	Add a cube, offset by 4 units	
P1	I'm typing GX-*2*, my second cube is now *two units to the left in the -X direction*	Navigation
	I make GZ and make -*2*, same cube as GZ-*2*	
	I press X, I send *2, +3*	
	We make GZ and *move -2,* we are *in object mode*	
P2	I'm taking -*2 in the Y direction*	
	GX-*2 units*, GY-*2 units*, GZ+*2 units*	
	The *farthest* and *topmost* cube *in the Y direction*	
	You take -*2 units in Y*	
P1	We will *press A* and *press X,* we will delete all objects	Physical Interaction
	I *press G*, I *press Z*, and *it's +2*	
	I *do shift+A, click* add, *click* the cube	
	again I *leave with a right click*, I do *GX*	
P2	Add a cube with *shift+A*	
	We copy with the *shift+D command*, *right-click*, and the object is in place	
	Press the G key to take Z-2 down	
	Move 2 units up by *pressing G*	
P1	When we are on the *drawing screen* we have *a cube on the stage, a camera, and a light*	Visual Interaction
	On the right, there is a material button that *looks like a world*	
	We are still *on the object mode screen* and we hold our mouse on the drawing screen	
	I click once somewhere in the space, taking all the *cubes into the window*	
	I want the first cube I made *to be selected in yellow*	
P2	Must be *at the origin of the 3D cursor*	
	On the right there is a material screen in the form of *checker material above the globe,* you can find its icon *in the lower right*	
	You can open the *increment at the top of the screen*	
	When you *open the magnet from the snap tool*, it will snap you at increments.	
	A *circular screen* will come, you select *the bottom one*	

The relations of the cubes in the reference models with each other were able to reach their position in the model with the metaphorical descriptions of the participant in the role of the narrator. The labeling on the transcripts of the participants was inspired by the metaphor classification of Fineman (2004). The spatial metaphors used by the participants during the test process were categorized as Direct manipulation, Navigation, Physical Interaction and Visual Interaction. This categorization shows an intention towards what the participants expressed spatially in the modeling process, and they are shown in Table 2 as *spatial intention*.

4.2 Evaluation

Both participants benefited from their spatial interpretation skills in the process they assumed the role of narrator, and as a result, the metaphors they used changed in this context. In the modeling process, the participants performed actions on and with objects in the virtual environment, frequently using metaphors of direct manipulation. Expressions such as *adding a cube, selecting the components, painting shapes* are based on the metaphor of 3D OBJECT IS A PHYSICAL OBJECT.

During the narrative process, the participants, who explored the model in front of them from different perspectives, with various mouse interactions, made the spatial relationships within the model directly according to the Blender program in their minds. Both participants described the positions of the model components directly using the Cartesian system and metric units without any difficulty. Cartesian-based description, which led to the adoption of a quite different expression, created the navigation metaphors used in accordance with the X, Y, and Z coordinates. Participants benefited from expressions such as *taking -2 in the Y direction, make GZ* and *move -2, come to the origin* for each object they mentioned throughout their narratives. For this reason, 3D ENVIRONMENT IS THE CARTESIAN COORDINATE SYSTEM has been deduced for the navigation metaphors of the 3D environment.

In addition to direct manipulation and navigation, human interaction takes place in Fineman (2004)'s metaphors in the context of HCI. Human interaction is based on the idea that a person interacting with a computer can communicate as if there is a human being in front of him. Although this approach, which includes a very broad conceptual framework, forms the basis of interaction with computers, within the scope of this case study, human interaction has been interpreted as 'physical' and 'visual' based on the interface interactions of the participants in the design process. Physical interaction includes physical action-oriented interactions in the expressions used by the participant while describing the model. These interactions are mouse-based like *clicking on the cube, leaving with a right click*, and keyboard-based like *making GZ to move, pressing shift+A*. These physical interactions described by the narrator are actually shortcuts that make it easier for the modeler to follow the right paths. Although each platform has its own shortcuts, knowing these shortcuts allows speaking the language of the platform. Therefore, it can be called SHORTCUTS ARE THE LANGUAGE OF THE PLATFORM. As the vocabulary of a language expands, the usage of that language also gets richer. Knowing these physical interaction ways for the platform used has the potential to strengthen the user's dialogue with the interface.

Another interaction is based on visual elements in the interface. The visual interaction, which supports the interaction of the user physically through various hardware, supports the metaphor of INTERFACE COMPONENTS ARE THE FIXED ASSETS OF THE PLATFORM. Because, although the program interface used by the modeler was not open in front of them during the narration process, when both participants wanted to choose a tool through the interface, they directly described the location and visual form of this object. Using expressions like *on the right there is a material screen, a circular screen will come and select the bottom button*, explaining the spatial positions and visual forms of the components in the interface paves the way for interpreting these visual components as fixture elements.

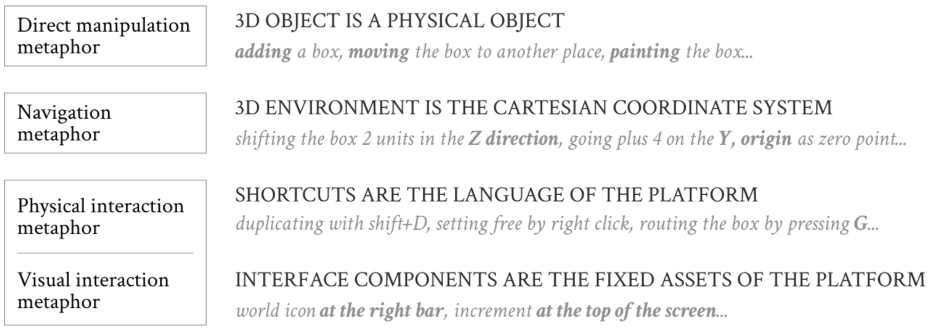


Figure 3. UI metaphors according to the case study. Source: Authors, 2023.

4.3 Constraints

Since only two participants took part in the pilot study, the findings are likely to be open to subjective interpretations in terms of individual experiences and interactions. In the case study, which is planned to be done in the future and which is aimed to be evaluated with a wider scenario, it is aimed to make a more subjective evaluation with more participants. In this context, the findings obtained from the pilot study were important in terms of presenting grouping and evaluation criteria that would make it easier to construct the details for a similar scenario.

Another limitation of the study is the language and translation situation in the pilot studies. The tests were conducted in the native language of the participants and authors. The metaphor expressions given in the tables in the text were later translated into English by the authors. Although studies on metaphors are built on a language-oriented problem, as Lakoff and Johnson (1980) stated, metaphors also offer an approach that shows the flow of thought and action, and in this context, they do not constitute an obstacle for communication.

5 Conclusion

The process of establishing inter-object relations in space in the minds of designers, together with the design tool interface used, is based on spatial metaphors. Interface functions, which are integrated with the designer's experience with them, emphasize that the relations between objects in space should be evaluated through different metaphors. The case study within the scope of this research was carried out through narratives to make it easier for designers to express their unconscious actions in their own design processes. Spatial metaphors were grouped as direct manipulation, navigation, physical interaction, and visual interaction, with reference to the spatial narrations of two expert 3D modelers. The most important proof that the participants do not think independently of the interface when creating objects in their minds is the frequent reference to UI components in the metaphors used and even the description of objects with a Cartesian system in space. This indicates the necessity of using new functions and new metaphors that will strengthen the construction of spatial relations by reconsidering the common UI metaphors in the future. In the next stages of the research, it is possible to deepen the research on spatial metaphors and suggest interface metaphors in the light of more comprehensive data.

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