LANGUAGE AND MOVEMENT IN CAD APPLICATION

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Abstract. The paper attempts to explain some of the fundamental concepts as they relate to the experience of movement in space and the representation of walking-through or fly-over in architectural space. My goal is towards improving existing movement-in-architectural-space representation tolls. This study involves current research in cognitive science, in the domain of vision and spatial reasoning, in which we attempt to built a rudimentary model of the apparatus through which people experience space, and, in particular, architectural space. These conceptions necessitated the analysis of language. From the studies we can draw up a small number of critical qualities that have to be present in an improved version of a new movement-in-space representation tool. As opposed to existing computational tools representing movement in space navigation, the tool we build can offer a more immersive interactive experience for evaluating design solution alternatives and predicting moving-in-space experience.

1. Introduction

There is a growing interest in the nature of the psychological experience of movement in space as it relates to the representation of walking-through, or fly-over, in architectural space. This interest has resulted from a realization that the architectural profession lacks the means to understand and explore the experience of movement, as well as the means to describe it in a visual or a verbal fashion. The existing tools, especially the computer-based tools that attempt to describe and portray movement are flat and lack the ability to imitate the actual experience of movement. Characteristically, the impression one has is of passivity, detachment, neutrality, and disinterestedness that are in sharp contrast with the actual sense of active engagement and focused involvement one has in real life when moving inside or around buildings. More importantly, the experience gained in simulated environments is of very little help to designers or to future users since it does not correspond to the anticipated

experience the finished project. Therefore, the predictive power of present movement-in-space representation tools, including CAD systems where our expectations have been directed during the last two decades, is very limited. Therefore, we have to reach to the roots of spatial experience, and to pose some basic questions which will enable us to understand what it is the feel of "being in space," acting in it, and moving through it.

The aim of this paper is to examine and explain some of the basic reasons of the failure to describe movement. In order to identify what is missing from the current representational systems of movement-in-space. We carried out a systematic analysis of the fundamental pre-suppositions of movement with careful attention to the perceptual system and a primary concern with the cognitive facilities in identifying and categorizing objects.

The theoretical basis of this study stems from the work of Ray Jackendoff. Jackendoff states in his book "*Language of the Mind*" that the bridge between natural language and isomorphic representation is the conceptual structure, to use his words "*Meaning, of course, is presumably the reason for there being such a thing as language at all, since the language faculty is at bottom a device for externalizing and communicating meaning. I will use the term* ***conceptual structure*** *for the level of representation that encodes meaning*." (1996, P. 7-8) Jackendoff claims that conceptual structures are linked to spatial representation and linked to language facility. He attempts to reveal spatial cognition in language while this study aims to reverse the process, and to reveal spatial language, and spatial cognition in spatial representation.

Based on current research in cognitive science, in the domain of vision and spatial reasoning, we built a rudimentary model of the apparatus through which people experience space. We draw, in particular, from research by Stephen Kosslyn and Ray Jackendoff.

The ability to navigate in space should be understood through the dichotomy between the **objective** and **subjective** points of view. Plans, sections, and elevations are all objective descriptions of objects. Perspectives of buildings offer a subjective description and, once chosen, would usually show a suggestive limited interest, a frozen moment in time and space, a subjective point of view. In between these two poles there lies spatial cognition. In order to attain spatial cognition, i.e., the ability to represent the environment and act upon this representation to form a decision, one has to be able to distinguish between the object in a scene and its background. Language can serve as such a tool.

2. Language and Image

But where do spatial representations come from? And how is one representation derived from another? Processes are the active components in information that

transforms or changes one representation into the next. One is constantly observing processes that divide into events. Those events are thought of as "states of mind" that are constant. The examination of these states of mind makes implicit information explicit.

Further, we may explore two kinds of knowledge:.

1) **Declarative knowledge** – the ability to acquire and identify objects. L. Liben (1981) shows that declarative knowledge is the mental database of specific spatial features and it is regarded as landmark knowledge. Declarative knowledge underlies the ground to procedural knowledge.
2) **Procedural knowledge** – Golledge (1993) argues that procedural knowledge is used to synthesize declarative knowledge into information that can be employed to facilitate action and locate objects in space. In addition, it incorporates information such as angles, direction, and orientation.

   Movement, in this article, is perceived as a procedural knowledge, which implies that only certain movements can be explored. It also means that a movement that is generated from a metaphor, for example, is outside the scope of this investigation.

2.1. ANALYSIS

The examination of how one describes what one sees as one moves is an expression of the speaker's underlying cognitive states. The ability to navigate in space should also be understood through the dichotomy between the objective and subjective points of view. Plans, sections, and elevations are all objective descriptions of objects. Perspectives of buildings offer a subjective description. Once chosen they would usually show a suggestive limited interest, a frozen moment in time and space, a subjective point of view. In between these two poles there lies spatial cognition. In order to achieve spatial cognition, i.e. the ability to represent the environment and act upon this representation to form a decision; one has to be able to distinguish between the object in a scene and its background. Language can serve as such a tool. The spatial predicate is marking a location, an operation that designates it as one to be remembered. The spatial predicate also marks the referent and relatum position in space and arranges its part to be accessed. The spatial predicate takes the format of a predicate, a referent and a relatum:

(1) Referent: The features of an object.
(2) Relatum: The reference object in the background.
(3) Predicate: Spatial relationship between the referent and the relatum.

This process is defined in a sense by Filmor's (1968) "Case Grammar" and later by Talmy (1980)

2.1.1. Place and Path

The set of ontological categories such as OBJECT, PLACE, PATH, EVENT, and STATE, are related in language by formulation rules and constraints. Firstly, consider the internal structure of PLACE concepts. According to Ray Jackendoff (1987 p.163) the prepositional phrases such as "here," "that away," "on the roof", and "in the park" are being used to pick out PLACE and PATH in the projected world. As observed prepositional phrases in English may designate a verb or verb construction that does not require or cannot take a direct object, such as "here," "that away," "forward," or "downstairs." Alternatively, it may explicitly mention a reference object as the object of preposition, as in "on the roof," "under the ceiling," or "in the room." It may mention two reference objects, as in "between the house and the park" and "across the road from the firehouse."

According to Ray Jackendoff (1987 p.164) the internal structure of PATH often consists of path-function and a reference object, as expressed by phrases like "towards the house," "around the house," and "to the floor." Alternatively, the argument of path-function may be a reference place. This possibility is in phrases like "from under the table" where "from" expresses the path-function and "under the roof" expresses the reference place. Preposition such as "into" and "onto" express both a path-function and the place-function of the reference place. For example “The man ran from under the Shelter.” Many preposition in English - for example, "over," "under," "on," "in," "above," and "between" – are ambiguous between a pure place-function and To + place-function. For example: “the man is under the shelter.” and “the man ran under the shelter.” One of the ways to view an architectural building is to travel along a route. A route is a sequence of procedures between two nodes requiring decision taking. The path is then the course of action or conduct taken between two nodes. “The internal structure of a path often consists of a path-function and a reference object… alternatively the path function may be a reference place.” Jackendoff (1983 p. 165) suggests that paths can be divided into three broad types, according to the path's relationship to the reference object or place.

The first classification, **bounded paths**, includes source-path, for which the usual preposition is "from," and goal-path, for which the preposition is "to." In bounded paths, the reference object or place is the endpoint of the path. For example “the man walked across the room.”

In the second class of paths, **direction**, the reference object or place does not fall on the path, but would if the path were extended some unspecified distance. "Away from" and "towards" are the most common. For example “ the man walked into the room.”

In the third class of paths, **related path**, the reference object or place is related to some point in the interior of the path. The verb "pass" is one of them. For example “the man passed by the room.”

Path is then the basic element of a route, but one needs more than this to formulate a movement in space representational tool. When one walks along the path one stops, looks around, adjusts or changes his path, and looks at objects of interest. That is to say some of the views have to do with way finding and the decisions that accompany it and some about information that one acquires through looking at objects. In order to control the path one needs to differentiate further between the observer and the object of his attention. This is a discrete representation as opposed to continuous pointing devices. The use of language in this case is not able to direct the observer right or left but rather in pointing to objects through language and vice versa i.e. pointing to the observer.

2.2. FRAMES OF REFERENCE

Language makes use of different frames of reference for spatial description; they are used to identify places in directing our actions, in deciding where to move. Frame of reference - "*a locus or a set of loci with respect to which spatial position is defined*." Campbell (1994 p.8.) The co-ordinate system, centered on the viewer, seems generally to be based on the planes through the human body, giving us an up/down, back/front and left/right set of half lines. Such a system of co-ordinates can be thought of as centered on the main axis of the body and anchored by one of the body parts. Although the position of the body of viewer may be one criterion for anchoring the co-ordinates, the direction of gaze may be another, and there is no doubt that relative systems are closely hooked into visual criteria. “*Language does not use a universal reference system, and the choice of frame of reference in linguistic coding correlates with preference with the same frame of reference in nonlinguistic coding over a whole range of nonverbal tasks*.” Levinson (1996 p.125)

Egocentric frames of reference (intrinsic) - are those that "*define a spatial position in relation to loci of the body*." Campbell (1994 p.8.) The frame of reference that we use to identify places in directing our actions, in deciding where to move to, is an egocentric frame. The notion of egocentric space is a psychological notion. The egocentric axes have to be taken as primitive, relative to the body image. The egocentric frames are a particular class of object-centered frame; namely, those centered on the body or a part of the body. The short-term body image gives the subject a particle grasp of the ways in which he can act the possibilities of movement open to him. According to Levinson (1996) it is object centered and uses the co-ordinates of left, right, in front, and behind.

Allo-centric frames of reference (relative or deictic) - the position defining loci are external to the person in question. The allo-centric frames of reference

presuppose a 'view-point', and a figure and ground distinct from it, thus offering a triangulation of three points and utilizing co-ordinates fixed on the viewer to assign directions to figure and ground. In allo-centric frames the viewer is environment centered. The viewer is centered and uses a set of co-ordinates, left, right, in front, and behind.

Absolute frames of reference - the position defining in absolute terms like North, South or Polar co-ordination. Among the many uses of the notion "absolute" frame of reference, one refers to the fixed direction provided by gravity (or the visual horizon under canonical orientation). Origin is the reference. In absolute frames it is environment centered and uses ether Cartesian or Polar co-ordinates.

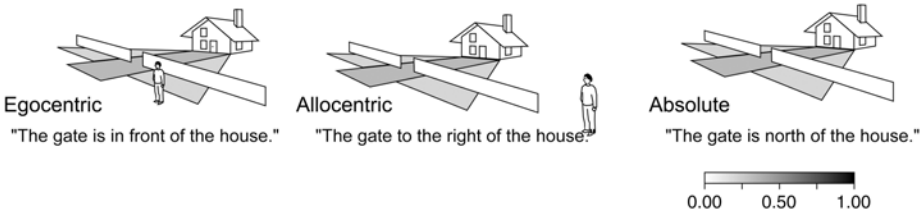

Figure 1. The different frame of reference and the degree of discretization. (The darker the standing the higher the degree of accordance of the corresponding acceptance relation.)

Let us start with the example "the gate is in front of the house." (Figure 1) In English this entails that the gate is between viewer and the house, because the primary co-ordinates on the viewer appear to have been rotated in the mapping on to the ground object, so that the ground object has a "front" before which the gate is situated. The sentence “the gate is to the left of the house” could be an allo-centric frame of reference dependant on established knowledge. One is not sure where the viewer position is, it can be in front, but it is not necessarily so. What is the attribute of the different object? According to Levinson (1996 p. 140) “*English is (apart from top and bottom, and special arrangement for human and animals) largely functional*.” For a manufactured artifact the way we access or interface with the object obviously determines its front- this is the case with a building that has one entrance. For the inherent features determine other phenomena, co-ordinate systems, surface and the object to be used in relation to the observer. Having established the front, it might be used to anchor a ready-made system of opposites front/back, sides, and so forth. As would be the case with any centralized symmetrical building or cylindrical building.

2.3, IMAGE - SCHEMA

As Kant in the *"Critique of Pure Reason"* suggested that *"the image is a product of the empirical faculty of reproductive imagination; the schema of sensible concepts, such as of figures in space, is a product and, as it were, a monogram, of pure a priori imagination, through which, and in accordance with which, images themselves first become possible. These images can be connected with the concept only by of a schema to which they belong.*" (1787, 1965 B 181) thus there is a relationship between representation and the way meaning is assigned that imply a structure. The schema is such a device that depicts the conditions between things in the world to which a category can apply. According to Jackendoff (1987) the crucial modules for the connection of language and spatial cognition are the conceptual structure and spatial representation. The idea is that these two levels share the work of cognition, thus conceptual structure encodes "propositional" representations, and spatial representation is the locus of "image schema" or "mental model" representations. Jackendoff's conceptual structure hypothesis states that "*there is a single level of mental representation, conceptual structure, at which linguistic, sensory, and motor information are compatible*." (1987 p. 17) According to Kosslyn (1995) this sub-system postulates that visual memories are stored in an abstract (propositional?) format and that an image is formed in order to make accessible information about the local geometry of a shape.

Image-schema is a process of systematic selection of certain aspect of the referent scene to represent the whole. Image schemas and metaphorical models are required to represent the meaning of the expressions. The senses of each expression form a structured category, with a central member and links defined by image-schema transformations and metaphor. The non-central senses cannot predict from the central senses, but are none-the-less not arbitrary. Rather less central cases, image-schema transformations, and metaphorical models motivate them. The image schemas or schematization is a process that involves the systematic selection of a certain aspects of the referent scene to represent the whole. Image schemas are used to navigate, reason and structure the environment. Image schemas are also important to perform way finding. Relating schema to real world is based on topological concepts.

2.4. AMBIGUITY

All this information leads us to the next question: what is the relationship between spatial words the objects in the real world, that is the action in spatial relations? "*There are certain natural relationships among image-schema motivate polysemy, not just in one or two cases, but in case after case throughout the lexicon*." Lakoff (1987 p. 440) Polysemous words, like a single core meaning that accounts for all and the various senses cannot represent certain objects. In the case of "*over"* Lakoff (1987) shows that the word 'over' has different meanings, for example "Jim is over the bridge" and "Jim drove

over the bridge" or "signs where posted all over the bridge". In all of the 'over' sentences there is a different meaning and location of subject. Most schemas span several of these categories. In contrast to Lakoff (1987) Jackendoff (1996) attempts to understand language form within its structure and its relationship within by the use of syntactic context in which those elements occur through the use of cognitive and grammatical constraints. Those constraints though, do help to differentiate between the movement and observation but still leave some problems in partitioning of a scene and establishing a frame of reference. Spatial expression such as 'in front' operates on approximate partitioning of the domain, a discretization (polysemy) into regions with a large degree of ambiguity. (See Figure 1) The partitioning divide the domain into acceptable zones. The discretization of objects depends on the dimensions involved, scale-related to size of object, shape, typology-relation between parts, position and orientation, multi-objects, unknown factors, and time. In order to solve some of discretization and polysemy computational models have employed different methods; the most famous are the fuzzy logic and multi criteria.

2.5. THE IMAGERY DEBATE

Until now we have talked about language and representation without asking a crucial question what is the difference between language and image? This question has sparked a great debate about how the mind stores information. The debate was between the analog and prepositional. The analog position was that visual images are the main source for the mind to process information. The propositional position was that structural description was constructed out of abstract propositions. Out of this debate certain elements where brought forward.

The fundamental difference between imagery and proposition lies at their treatment of the relations among objects of the represented world, out of this peculiarity one can draw further distinctions. "*Propositional representations are simply those in which there exist relational elements that model relations by virtue of themselves being related to object elements*." Palmer (1978 p. 294) Language refers to objects (nouns, pronouns, etc.) are related in syntactically ordered strings through relational words (verbs, prepositions, etc.). For example, the sentence "Notre-Dame cathedral has two turrets on the facade " specifies a relationship between the turrets and the main architectural volume that can only be understood through the predicate "on." Language can thus be indeterminate, on the other hand image representation must be determinate. For example, I might say "Notre-Dame cathedral has turrets on the façade." Drawing the Notre-Dame one must draw the two turrets otherwise the drawing could be mistaken for another cathedral. Thus image representation resembles that which it represent and therefore **isomorphic**.

Thus one can say that through language one can point discretely by using a predicate while image representation does not have this distinction and is continuous.

Architecture in modern times uses the combination of language and image in plans, elevation and sections. This is done in order to provide the action orientation construction of the building. In contrast architects usually do not annotate the perspective that they produce. In the future this stage might be preparation for the animation of the 'walk through' or 'fly over.'

3. Devices

Following the above investigations we can draw up a few critical qualities that have to be present in an improved version of a new movement-in-space representation tool. They are:

1) A device that provides schematic structure for selecting certain aspects of the referent scene to represent the whole in relation to specific targets for the use of the information to be supplied by the system.
2) A device that permits shifting of attention through which one focuses on the visual scene as one moves through space in time in relation to specific targets for the use of the information to be supplied by the system.
3) A device that permits being conscious of several frames of spatial reference that specify the position of the viewer to the surrounding objects and the position of the objects with each other the same time as one moves in space: egocentric, allocentric, absolute, combining with action.
4) A device that differentiates types of path that can integrate the topological organizational devices.

4. Conclusion

We have shown how a linguistic system of representation differs, from a system based only on visual diagrams as it is reduced in computer aided graphic applications. We have also suggested that a linguistic system can inter-act with, and complement, a visual-graphic system. This is established through Jackendoff style conceptual structures that are linked to spatial representation and language facility.

The challenge to build an application that uses both systems, applying spatial propositions in relating path with verbal directions has not yet been met, although great strides have been taken. What those findings suggest is that language can increasingly help us develop more powerful representation systems helping CAD navigation. Language is able to distinguish between egocentric frames of reference, allo-centric frames of reference, and absolute frames of reference in walk through, fly-over situation. Those frames of reference are used in combination with the path procedure can easily be

interchanged as one describes and directs movement in the built environment. One can anticipate that discretization between these frames will be solved by computational models that and employ different methods like fuzzy logic and multi-criteria. In the future more applications are expected that use language in combination with existing graphic-visual virtual spaces to facilitate better navigation, a toll whose development presupposes a good grasp founded on cognitive sciences, conceptual system of spatial reasoning.

Reference

Campbell, J. 1994 *Past, Space and Self.* MIT Press Cambridge Massachusetts

Fillmore, C. 1968 The case for the case. in E. Bach & R. Harms (Eds.) *Universals in Linguistic Theory.* New York: Holt, Rienhart & Winston.

Golledge, R. G. 1993. Geographical perspectives on spatial cognition. in T. Garling & R. G. Golledge (eds), *Behavior and environment Psychological and geographical approaches* (pp. 16-46). North Holland: Elsevier.

Jackendoff, R. 1997 *The Architecture of the Language Faculty.* The MIT Press Cambridge Massachusetts

Jackendoff, R. 1983 *Semantics and Cognition.* MIT Press Cambridge Massachusetts

Kant, I. (1787) *Critique of Pure Reason* Trans. N. K. Smith St Martin's Press New York (1965)

Kosslyn, S. M. 1995 *Image and Brain ,The resolution of the Imagery Debate.* The MIT Press Cambridge Massachusetts

Lakoff, G. 1987 *Women, Fire, and Dangerous Thing, What Categories Reveal about Mind* University of Chicago Illinois.

Levinson, S. Frames of Reference and Molyneux's Question: Crosslinguistic Evidence in p. Bloom, M. A. Peterson, L. Nadel and M. F. Garett (eds). *Language and Space.* MIT Press Cambridge Massachusetts

Liben, L. 1981. Spatial representation and behavior: multiple perspectives. In L. S. Liben, A. Patterson, & N. Newcombe (Eds.), *Spatial representation and behavior across the life span.* New York: Academic Press.

Palmer, E. S. 1978 Fundamental aspects of cognitive representation. In E. Rosch & B.B. Loyed, (eds), *Cognition and Categorization.* 79-98. Lawrence Erlbaum Associates, Publisher, New Jersey

Palmer, E. S. 1999 V*ision Science Photons to Phenomenology.* The MIT Press Cambridge Massachusetts

Talmy, L. 1983. How language structures space. In H. L. Pick, Jr., and L. P. Acredolo (eds), *Spatial orientation: Theory, research, and application.* 225-282. New York: Plenum Press.