Designing Space in Virtual Environments for Aiding Wayfinding Behaviour

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Abstract: The aim of this paper is to develop an architectural way of thinking about designing space in a virtual environment, in order to inform human wayfinding behaviour. Several generic objects and spatial elements that a virtual environment consists of are suggested, their spatial significance and formal characteristics are identified and the way that these affect human wayfinding behaviour is also considered.

Keywords: Virtual environment design, human factors of virtual environments.

1. Introduction

1.1 Aim and context

This paper documents a research project which deals with the architectural aspect of *virtual environment* (VE) design. The aim of this project is to develop an architectural way of thinking about designing space in a VE by studying the significance of spatial elements in a VE for human wayfinding behaviour.

VR may be considered as the ultimate medium for producing representations of architectural designs, as it is the only technology capable of simulating the experience of being and moving within a designed environment prior to its construction. This paper, however, is concerned with how architectural design may contribute to the design of VEs. It particularly refers to a class of VEs defined in a World Design Inc. report (1993, p.12) as *abstraction* or in other words VEs which represent very complex material world information or information that has no physical representation. The VEs considered here, however, do not support continuous change and consequent spatial re-arrangement of data in a dynamically evolving three dimensional context, according to pre-determined rules. In order to implement a series of architectural concepts, at this stage, it is essential that VEs have been designed prior to interaction and that they are visualisations of predetermined data sets

This paper does not refer to *simulations*, where the aim is to realistically imitate real objects and events. Architectural form in the built environment is often dictated by physical constraints. Due to the lack of such constraints in a VE, elements of space do not need to resemble any kind of particular real-world spatial elements. However, most VEs that we witness today are designed by non-architects who have not been trained to think and compose in three-dimensions for accommodating human activities. As a result, the forms and spaces they can come up with are mostly simulations of real world equivalents. While taking into account that specific applications may require the implementation of real-world constraints, one cannot help thinking that imposing such constraints and imitating real-world forms in most VEs is like using a film camera to record a performance on a theatre stage (and indeed this is what had happened at the beginning of the history of cinema).

This paper argues that if we want to generate new methods of composing form in order to define space in VEs, we may build on what is known about space in the real world while avoiding the imitation of real world forms when there is no specific need for them. It is exactly at this point that an architectural way of thinking may prove useful for developing novel ways of designing space in VEs, according to the medium's intrinsic characteristics. (Bridges and Charitos, 1996– Creativity and cognition)

1.2 Spatial cognition in a VE

When a user interacts within a VE they are likely to be involved in the following two situations:

- moving within a VE or
- doing something, somewhere within this VE.

This paper is based on the assumption that the cognitive processes involved in moving or doing something in the real world are also involved when these situations are located in a VE.

In both situations, the user is involved in a perceptual cycle in which, according to Bell et al. (1996, p.67) "we bring expectations, experiences, values and goals to an environment; it provides us with information and we perceive it through activity. One part of this activity is simple exploration for orienting ourselves in this environment; another part is designed to find strategies for using the environment to meet needs and goals; a third part is related to establishing confidence and feelings of security within the environment." Through action therefore, we perceive *environmental information* (*sensory, memory, inferential*) which is essential for plan and decision making preceding our actions.

In the real world, such environmental information is conveyed to us *directly* (signs, maps, etc.) or *indirectly* (architectural and spatial characteristics of a setting) (Passini, 1992, p.90). Similarly in VEs, the setting defined by a certain arrangement of objects may indirectly inform us of forthcoming events or direct us towards significant spaces. If we want to design VEs where the arrangement of spaces aids the users' wayfinding behaviour in such a manner, we have to investigate:

- what types of objects would we design in such VEs,
- what types of spaces would these objects define and
- how would these spaces affect human wayfinding behaviour.

Earlier work (Charitos, 1996) has attempted to answer these three questions, based on how we think about space in the real world, as seen from a phenomenological viewpoint. A second phase of this project focused on how we think about and remember space when navigating in our environment, as seen from an environmental cognition perspective (Charitos and Rutherford, 1996). This has led to a better understanding of the stages involved in the acquisition of spatial knowledge and consequently to a definition of the possible elements of a VE, according to how these are perceived and recorded in memory, during a wayfinding situation.

According to these findings and in response to the above mentioned questions, a hypothesis was introduced which suggested:

- a taxonomy of the possible objects that a VE consists of
- the spatial elements that these objects define,
- the characteristics and structure of these elements,
- how these elements affect human wayfinding behaviour.

It is expected that by understanding the spatial significance of the elements that constitute our environmental image in VEs along with how we 'read', think of and remember these elements, we may begin to understand how to design and structure such elements for the purpose of aiding wayfinding behaviour.

2. Hypothesis

2.1 Objects in a VE

2.1.1 Landmarks

When we navigate in a VE, we firstly recognise those objects which are predominant within the context of the environment as seen from our subjective point of view (behaviour, social aspects, experiences, etc.). We call these objects *landmarks* and the type of spatial knowledge that we acquire at this stage is called *landmark knowledge*.

Lynch (1960, p.48) defines *landmarks* as point-references which are singled out from alternate possibilities available in the environment, by virtue of their form or function, for purposes of identification, structuring and orientation. Landmarks are mainly static but could also be mobile if their motion is sufficiently slow and regular. When distant they may symbolise a constant direction or be used as radial references. When local they may be used as clues of identity or structure.

Burnette (1974, p.179) stresses the symbolic character of landmarks and the fact that they are external to the observer. He interprets Lynch's concept of landmark as identifying a class shared by any singular referent for thought, any symbol or objective element. He also relates this concept to the architectural concept of mass (abstractly known fact) and the archetypal form of a tower (a selected symbol), which share an operational objectivity in spatial thinking (1974, p.181).

Lynch (1960) and Appleyard (1969) have suggested certain criteria, applicable to urban environments, which may also inform a VE designer on how to design a landmark so that it is easily singled-out within a VE. Accordingly, a landmark would be easily identified if:

- it has prominent physical features or
- it contrasts with its background, in terms of form and other characteristics (meaning, style) or
- it is visible from many locations or
- it is being used frequently or
- it performs a symbolic function.

2.1.2 Signs

The arrangement of objects in a VE provides the user with a purely plastic experience but may also communicate a certain meaning. This indirect meaning may range from a philosophical to a purely practical level, where it may affect user orientation and wayfinding within the VE.

Meaning in a VE may also be directly conveyed to the user by means of:

- *signs*, which indicate the past, present or future existence of a thing, event or condition and
- *symbols*, which are vehicles for the conception of things (Thiel, 1961, pp. 45-46).

These signs and symbols may be inherent or implicit in the configuration or relationship of the spatial elements in the VE or they may be parts of the objects themselves. They may also be visual and/or auditory. It is essential that a correspondence between the outer form and the inner meaning exists, as without this isomorphism the intended message may be misunderstood.

While landmarks (as defined in 2.1.1) are mainly symbolic objects which may inform a user for identification, structuring and orientation purposes, signs according to Passini (1992, pp.90-92) communicate specific environmental information needed to make wayfinding decisions; they tell the viewer what is where and they also specify when and how an event is likely to occur. Passini classifies them as:

- Directional signs, which designate direction towards a place, an object or an event in form of a name, a symbol or a pictograph and an arrow.
- Identification signs, which are the most elementary state of description of a location, usually perceived when the destination is reached; they identify an object, a place or a character in a VE.

- Reassurance signs, which act as checkpoints after a wayfinding decision is made, to reassure the subject that they are on the right track.

2.1.3 Boundaries

According to Ching (1979, p.108), space is "inherently formless; its visual form, quality of light, dimensions and scale depend totally on its boundaries as defined by elements of form". Similarly, a VE consists of *boundaries*, visual and/or auditory, which bind and subsequently define all spatial elements in a VE.

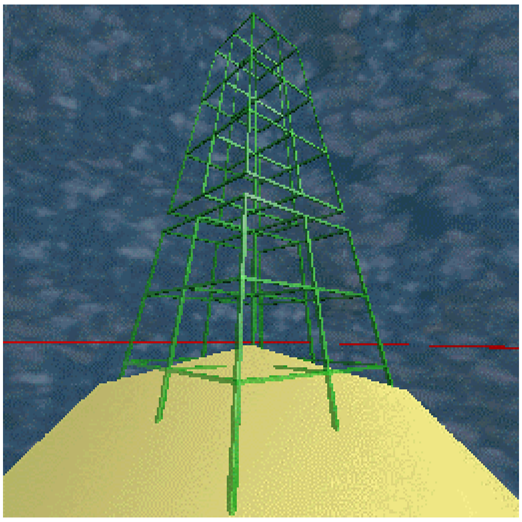

Figure 1: A landmark

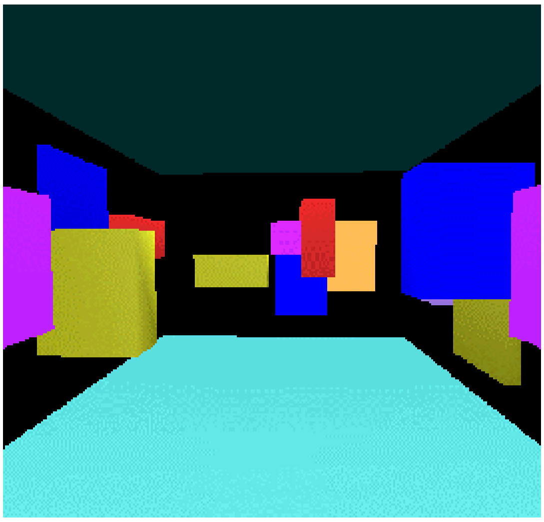

Figure 2: Vague boundaries

The form of boundaries does not need to imitate forms and characteristics of real world objects. This paper argues, however, that it is important to implement *collision detection* so that boundaries do not afford movement through themselves. Maintaining this real world constraint results in boundaries expressing a certain 'solidity' and thus defining spaces not only visually but also physically and functionally. If users were able to go through boundaries, these would loose their significance as space-establishing elements.

The appropriate design of boundaries may significantly simplify navigation within a VE, when collision detection is implemented. 'Solid' boundaries may prove a helpful constraint for guiding 6 degree-of-freedom movement within a VE. This principle may also become a starting point for designing functionally justified forms in VEs.

Boundaries may define a space in varying degrees of explicitness. The quantity of boundaries is not necessarily an indication of the explicitness with which a space is defined; the form of the elements and the manner in which they are arranged in space is equally important.

2.1.4 Thresholds

A third intermediate type of object is the *threshold,* which signifies the transition between spaces, while navigating in a VE. Since the 'solidity' of an object depends on whether *collision detection* is implemented on this object or not, a threshold does not have to be void to afford passage. Therefore, thresholds may be visible objects, similar to boundaries in that they may still define spaces by binding them. At the same time, they functionally differ from boundaries in that they afford movement through themselves.

Carefully designed thresholds may efficiently signify:
- the transitional experience of passing from one space to the other or
- the beginning and the end of a certain space.

The validity of this observation should be evaluated by experimentation.

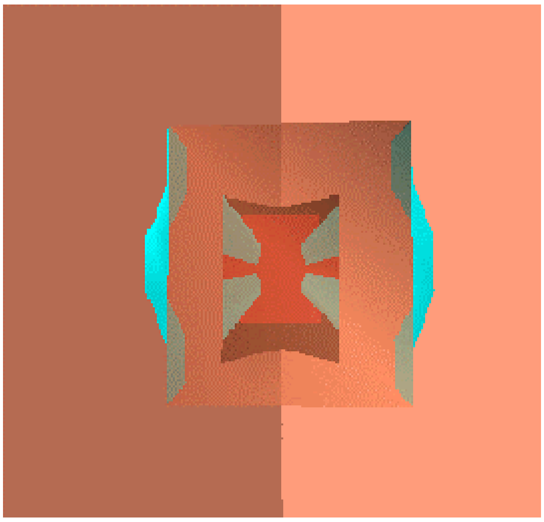

Figure 3: A threshold.

2.2 *Elements of space in a VE*

2.2.1 Place – a space for action

When navigating within a VE, a user may enter a desired destination in order to interact with certain objects which are found there. Such a destination, where certain static actions "take place" and these actions determine its character, will be called a *place*.

Bell et al. (1996, p.79) refer to the *place* as a component of spatial knowledge and describe it as a spatial unit to which we attach information like name and function and perceptual characteristics such as affective quality or affordances. Burnette (1974, p.180) defines a place as an activity setting", stresses its egocentric character and describes it as "a point locus for primary sensorimotor activity, which is only meaningful in terms of the user and his satisfaction and thus relates to the affective pursuit of the ideal of happiness." He also relates places to the archetypal concepts of the *cave* and the *home*.

In agreement with the above, Relph stresses the subjective character of place definition and tightly relates it to individual actions and intentions. He suggests (1976, p.42-43) that "places are the contexts or backgrounds of intentionally defined objects or groups of objects or events, or they can be objects of intention in their own right….Those places are defined largely in terms of the objects and their meanings. As objects in their own right, places are essentially focuses of attention, usually having a fixed location and possesing features which persist in an identifiable form…They can be at almost any scale depending on the manner in which our intentions are directed and focused."

According to Heidegger (1971, p.146,149), only when the relations between 'inside' and 'outside' are defined, can man 'dwell', 'stay in a place'. Only when humans feel secure in and identify with a certain place can they engage into activity there. It could be therefore suggested that, when in a VE, the feeling of security with which we engage into action in a place is related to the degree of explicitness with which this place is defined by its boundaries (see 2.1.3). As this hypothesis is considered crucial for the design of places, it is essential to test it by means of experimentation.

"A place that is being experienced as an 'inside' should generate a spatial sense of proximity, centralisation and closure." (Norberg-Schulz, 1971, p.20). A centralised form means concentration and decreases the apparent size of a place. Geometrisation of a place's form may enhance this effect. This hypothesis also needs to be tested in VEs, as it may be particularly important for designing places.

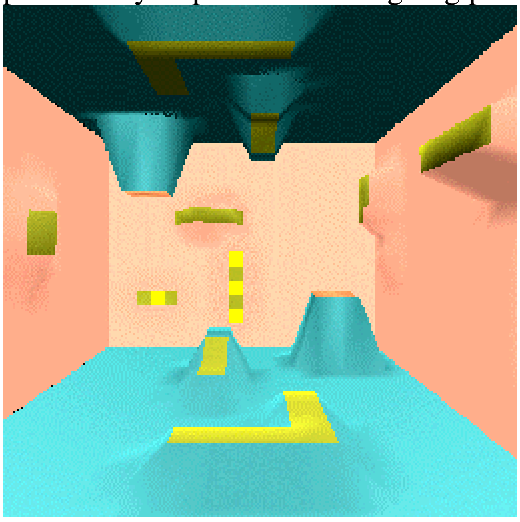

Figure 4: A clearly defined place.

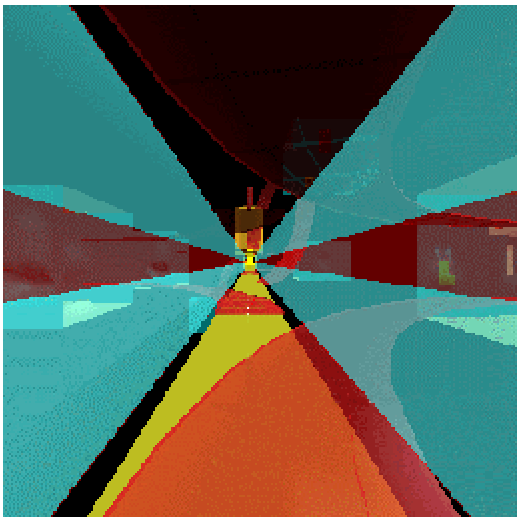

Figure 5: A view along a path.

2.2.2 *Path – a space for movement*

The distinction between the concepts of place and path is experienced as the tension between centralisation and longitudinality in our environments: "Whereas centralisation symbolises the need for belonging to a place, the longitudinal movement expresses a certain openness to the world, a dynamism which may be physical as well as spiritual." (Norberg-Schulz, 1971, p.26) Quite often the loci of tension between centralisation and longitudinality are the thresholds.

Burnette (1974, p.181) also stresses the distinction between egocentric character of a place and the behavioural continuity of the path. The former refers to relatively static activity whereas the latter refers to functional and dynamic activity, movement. He describes the path as a "movement channel" and relates it to the archetypal concepts of the road and the river and to the ideal of efficiency: the appropriate use of energy.
A *path* is a kind of space which implies movement and within which directions are always evident, due to the formal qualities of its spatial arrangement. When navigating in a VE, after identifying certain landmarks, we begin to think of the routes which connect these landmarks in order to acquire *route knowledge.* The physical expression of a route is the *path*.

Thiel (1961, p.40) suggests the physical requirements for a path by introducing the concept of 'run' as a space which has any one overall dimension (length, breadth or height) two or more times greater than any other dimension. Being inside a path induces movement of the eye or the body along an implicit direction which coincides with the greater dimension. Whether a space of such volumetric proportions would induce movement towards the direction it implies or not is a hypothesis which needs to be tested by means of experimentation.

When designing a path it is essential to make its structure clear to users so that they easily find their way along this path. Accordingly, the generic parts that the path consists of (the starting point, the direction of movement and the final goal) should be easily identified, so that users know where to start the movement from, which direction to follow and where the movement will end. It is also essential to provide some visual feedback for informing users of the distance they have traversed along the path and of their velocity, at each moment in time. This could be achieved by arranging rhythmically repeated elements at equal intervals along the path.

Finally, it is important to take into account that active engagement in navigation enhances the generation of route knowledge, considerably more than passive viewing does. We associate places with actions, kinesthetic feedback and with all other sensory input, in order to produce the knowledge necessary for informing navigation. (Gale et al., 1990, p.21) It could therefore be argued that users of immersive VEs may benefit more in terms of route knowledge acquisition, than when using a desktop VE, since they are involved in more active interaction through bodily movements for the purpose of navigation.

2.2.3 Intersection

When acquiring route knowledge, more information is coded at *intersections* of paths, where choices are made as opposed to between intersections. These spaces are the main decision points for wayfinding in an environment, as they afford viewpoints to actual and potential navigation choices and generally provide the user of the VE with richer and more complex environmental information. In addition, the novelty of having fresh visual

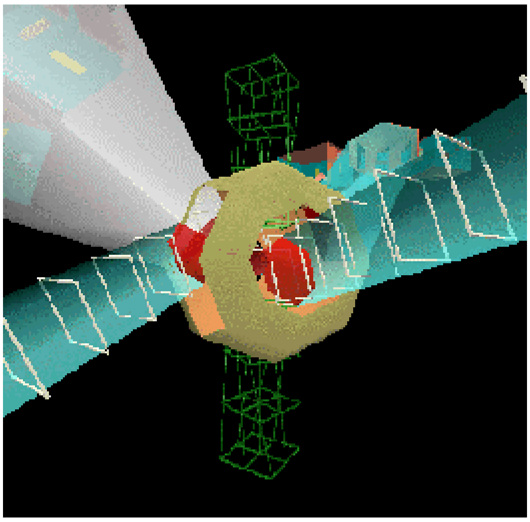

Figure 6: An intersection.

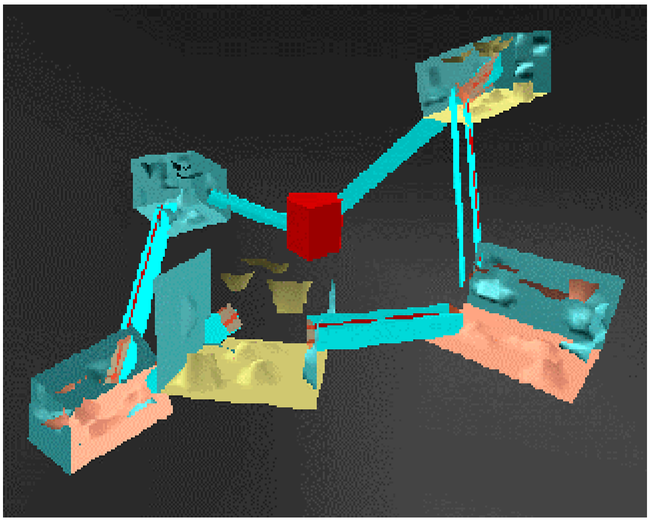

Figure 7: A domain

stimulus where new views are first seen may contribute significantly on focusing attention and encoding information. (Gale et al., 1990, p.21) Since intersections are the main decision points in a VE, it is essential to consider them as a separate type of spatial element, which can be described as *the space of interaction between other elements*.

If an object is located at an intersection, where path decisions are made, then we may associate it as a landmark. Smyth et al. (1994, p.312) have concluded that landmarks become positioned in space when they are crossed by many routes, therefore becoming a major part of the organisational framework for our mental map of the environment. Accordingly this paper suggests that if landmarks are positioned at intersections of paths within a VE, they are more likely to be identified as such and integrated in the environmental image of a user who navigates within this VE. It is also suggested that by being a part of the intersection, a landmark adds to the individual spatial character of the intersection thus making it memorable in association with this particular landmark. These hypotheses, however, are in need of experimental evaluation.

2.2.4 Domain – a subset of the VE

At the final stage of acquiring spatial knowledge when navigating in a real environment, we begin to think of the interrelationships of all the above mentioned objects by utilising the properties of *distance* and *direction* within three-dimensional space. This type of spatial knowledge may be seen as corresponding with the spatial element that Norberg-Schulz named *domain* (1971) and Lynch named *district* (1960). A *domain* is a subset of the whole VE which consists of a system of paths and places.

We relate to landmarks in a direct, experiential manner by seeing and identifying them. Similarly, we relate to routes by moving along them. Domains, however are mainly thought of rather than experienced, since we cannot directly experience them as a whole. Their production expresses man's general need for imagining his world as an "ordered cosmos within an unordered chaos...By structuring the environment into domains by means of paths and places" (Norberg-Schulz,1971, p.23). Similarly, it is necessary to structure a VE by means of domains, in order to be able to conceptualise it as a whole. In real environments, domains expand in two dimensions, due to physical constraints. In virtual environments, which are devoid of such constraints, domains may expand in three or more dimensions.

3. Current state of the project

This paper has suggested a taxonomy of possible objects and spatial elements that a VE may consist of and has attempted to define their spatial characteristics and to hypothesize about how these may affect human wayfinding behaviour in a VE. It has also been emphasised that several secondary hypotheses, put forward in section 2, were in need of testing by means of experimentation.

During the writing of this paper, a series of experiments were conducted. These experiments aimed at evaluating some of the above mentioned secondary hypotheses, which were considered to be particularly significant for resolving specific design issues and for suggesting how the proposed spatial elements could be designed. The results of these experiments are expected:

- to lead to the generation of a series of guidelines for designing objects and spatial elements in VEs and
- to suggest a series of new hypotheses in need of testing for informing the design of VEs.

References

1) Appleyard, D. "Why Buildings Are Known", Environment and Behaviour, 1, 1969, pp.131-159.

2) Bell, B., Greene, T., Fisher, J. and Baum, A.. Environmental Psychology. Orlando: Harcourt Brace College Publishers, 1996.

3) Bridges, A.H. and Charitos, D. "On Architectural Design in Virtual Environments", Proceedings of the 2nd Creativity and Cognition International Symposium, Candy, L. and Edmonds, E. (eds). Loughborough University, April 1996, pp.184-192.

4) Burnette, C. "The Mental Image and Design", in Designing for Human Behaviour, Lang, J., Burnette, C., Moleski, W. and Vachon, D. (eds). Dowden, Hutchinson and Ross Inc, Stroudsbourg, Pennsylvania, 1974, pp. 169-182.

5) Charitos, D. "Defining Existential Space in Virtual Environments", in Proceedings of the Virtual World '96 Conference. Stuttgart: IDG, 1996.

6) Charitos, D. and Rutherford, P."Guidelines for the Design and Exploration of Virtual Environments", Proceedings of the 3rd UK Virtual Reality Special Interest Group Conference. De Montfort University, Leicester, July 1996, pp. 93-111.

7) Ching, F. D.K. Architecture: Form, Space and Order. Van Nostrand Rheinhold, London, 1979.

8) Gale, N., Golledge, R., Pellegrino, J.W. and Doherty, S. "The Acquisition and Integration of Route Knowledge in an Unfamiliar Neighbourhood", Journal of Environmental Psychology, 10, 1990, pp.3-25.

9) Heidegger, M. "Building, Dwelling, Thinking" in Poetry, Language, Thought. Harper & Row, New York, 1971.

10) Lynch, K. The image of the city. MIT Press, Cambridge, Mass.,1960.

11) Norberg-Schulz, C. Existence. Space and Architecture. Praeger Ltd, New York, 1971.

12) Passini, R. Wayfinding in Architecture. Van Nostrand Reinhold, New York, 1992.

13) Relph, E. Place and Placelessness. Pion Limited, London, 1976.

14) Smyth, M.M., Collins, A.F., Morris, P.E. and Levy, P. Cognition in Action. Lawrence Earlbaum Associates, Hove, 1994.

15) Thiel, P. "A sequence-experience notation", Town Planning Review, vol.32, April 1961.

16) World Design Inc. "Designing Virtual Worlds", presented in Meckler VR 93 Conference, San Jose, June 93, adapted from WorldDesign's "A Report to the Evans and Sutherland Computer Corporation: A Virtual Worlds Guidebook" published in April 1993.