THE ARCHITECTURAL DESIGN OF VIRTUAL ENVIRONMENTS

ALAN BRIDGES and DIMITRIOS CHARITOS
University of Strathclyde

Abstract

The paper discusses the use of precedents from architecture, urban design and film to propose guidelines for the improvement of navigation and wayfinding in virtual environments.

1. Virtual Environments

The predominant use, so far, of virtual reality technology in relation to architecture, has been as a means of visually simulating architectural designs. In this respect, virtual reality 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 virtual environments themselves. More specifically, it refers to the problem of designing virtual environments from the point of view of enhancing the users' spatial awareness and, consequently, aiding the task of navigation and wayfinding within virtual environments. The need for addressing this issue is evident in the number of virtual environments which are not very efficient in orientating their operators (and are usually aesthetically displeasing as well).

This study has been carried out in relation to a particular class of virtual environment. World Design Inc., in a report on the design of virtual environments (1993, p.12), classified virtual environments in terms of the represented level of realism. They defined:

- *Hyper-realities*, which aim at representing the material world and reflecting its complexity and in which the creative design element is often limited to modeling interaction with the user.
- *Selective realities*, which are simplified representations of the material world and where some aspects of the environment are distorted or transformed and others are accurately represented.
- *Abstractions*, where the virtual environment represents a very complex material world information or information that has no physical representation. In this case, the designer must conceive an effective

abstraction of the complex information (which implies a transformation of meaning of what is being represented) and make this understood and responsive for the operator.

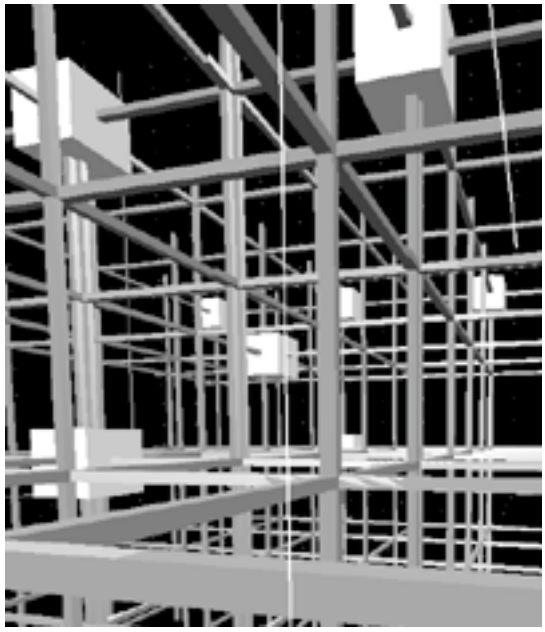

Figure 1. Abstract visualisation of data sets

This paper refers to the third type of virtual environment, "Abstraction". Such a virtual environment may consist of several spatial entities and events which have no real-world counterparts and which accommodate human activities such as navigation, interaction or communication within their three-dimensional, spatial, representational context. To this extent, the design of such a virtual environment is an architectural problem, and this paper considers architecture and urban design as appropriate precedents for informing virtual environment design. Virtual environments, however, have more aspects to their design than purely spatial elements. Time and movement are important and the precedents we draw on here are from cinema.

Metaphor is often employed as a means of abstractly representing complex information sets. Indeed, Bryson (1994) suggests that the employment of a metaphor is essential for the design of such a virtual environment. He refers to the different levels of metaphor that might be considered in a virtual environment:

1. Overall environment metaphor
2. Information presentation metaphor
3. Interaction metaphor

Metaphors, however, may be limiting in that they carry with them associations which might be irrelevant or inconsistent with what is being represented and therefore distracting for the application task.

This paper suggests that employing metaphors is not the only way of facing this problem. Although architecture and urban design are employed as appropriate precedents, an attempt is made to identify generic ways in which these disciplines may inform the design of virtual environments. Due to the lack of real world constraints, elements of space in a virtual environment do not need to resemble any kind of particular real-world spatial elements. However, in the generation of new methods of composing form in order to define space in virtual environments, we believe designers should build on what is known about space in the real world. This paper discusses the composition of space in such virtual environments, addressing the specific problem of wayfinding and navigation in the virtual environment.

2. Navigating Within Real Environments

In considering navigation in real environments, Passini (1992, p.82) suggests that three forms of environmental information (sensory, memory and inferential) are used in order to decide where to go next and how to get there. This environmental information is the essential criterion in determining the wayfinding solution. This paper restricts itself to information of a spatial nature, since it is mainly concerned with wayfinding as a result of the spatial arrangement within the virtual environment.

Passini (1992, p.90) suggests that environmental information may be obtained from various sources, either directly (by means of information booths, signs, maps, etc.) or indirectly (the architectural and spatial characteristics of a setting). This paper mainly focuses on this latter, indirect, information implied by the arrangement of objects in the environment in such a way that the sense of space, conveyed by this arrangement, helps operators anticipate forthcoming events and directs them towards spaces, which are significant for the fulfillment of the application task. Signs, being direct sources of environmental information, are considered, in the context of this paper, more as a part of the objective and static set of environmental objects than as dynamic tools which subjectively refer to each operator. Such specific tools and other direct ways for aiding navigation in virtual environments have been described in Darken and Sibert (1993) and Charitos and Rutherford (1996, 1997). Other aspects of virtual environment design in relation to their characteristics and sensory limitations have been discussed elsewhere (Bridges and Charitos, 1996).

3. Direct Spatial Meaning in the Virtual Environment

The arrangement of objects in a virtual environment provides the operator not only with a purely plastic, experience but with a certain meaning, as well. This meaning

may range from a philosophical to a purely practical level, which is informative for her orientation and wayfinding within the virtual environment.

Meaning in the virtual environment is also directly conveyed to us by means of signs and symbols; signs are indicating the past, present or future existence of a thing, event or condition and symbols 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 space in the virtual environment 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.

Signs according to Passini (1992, pp.90-92) communicate 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 signs 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 virtual environment.
- Reassurance signs, which act as checkpoints after a wayfinding decision is made, to reassure the subject that they are on the right track.

A sequence of directional signs may be employed for the purpose of aiding operators in finding their way towards a particular destination within an unfamiliar virtual environment. Several key issues involved in the use of signs in urban environments are identified by Passini (1992. pp.92-107), many of which are of relevance to virtual environments:

- familiarity with form and design of the sign. Brief, clear and visually structured message and indication of the decision needed to be taken by the operator, are all factors which enhance the effectiveness of a sign,
- signs with a similar message, or those which are a part of the same directional system, should be consistent in their graphic identity and also in the location that they are placed within the virtual environment,
- the continuation of directional signs should not be interrupted or discontinued as this will result in certain disorientation,
- the complexity and intensity of sensory stimulation provided by the surroundings may reduce the reception of information from the operator and the effectiveness of the sign system.

4. The Elements of Space in a Virtual Environment

Virtual environments, as a medium for creating synthetic, interactive experiences, are still in their infancy. When one tries to comprehend the intrinsic nature of this medium and in particular the characteristics of space and time in a virtual environment, other established time-based media such as film (or video) may prove useful precedents. Here, the work of the French philosopher Deleuze on image and movement in film, is used as a starting point for describing the structure and components of the spatiotemporal experience in a virtual environment.

The elements of cinema relate to Virtual Worlds insofar as they operate within a closed system. Following Deleuze (1983), we view the virtual environment as a closed system. Within this system framing is the art of choosing the elements which become part of a set (a relatively closed system) which includes everything which is present in the image. These elements consist of characters and props.

The closed system determined by the frame can be considered in relation to the data that it communicates to the viewer: it is "informatic". Considered in itself and in the nature of its parts, it is geometrical or dynamic-physical. Considered in relation to the point of view it is an optical system, simply related to the angle of framing. Given that there is a frame, there is inevitably an "out of frame". The closed system determines this out-of-frame, sometimes in the form of a larger set which extends it, sometimes in the form of a whole into which it is integrated. In film the out-of-frame implies that a character has not yet arrived, or more pertinately here, that the character is momentarily in a "zone of emptiness" and is invisible. Similarly, a virtual environment may be designed so that the framed part of the set includes cues that imply elements of the out-of-frame part of the set, which may be essential for an application task or to aid navigation.

Cutting is the determination of the shot, and the shot the determination of the movement which is established in the closed system, between elements or parts of the set. Thus movement has two facets: on the one hand, it modifies the respective positions of the parts of the set, which are like its sections, each one immobile in itself; on the other it is itself the mobile section of a whole whose change it expresses. From one point of view it is relative, from the other, absolute. Similarly, movement in virtual environments is experienced as change of position of the set's parts or of the viewpoint (virtual camera) in relation to the whole virtual environment. However, virtual environments differ significantly in that movement within them is largely determined by interaction of the operator with the system, whereas in film it is determined by the shot and consequently by cutting. Movement in a virtual environment is also partly determined by the virtual environment designer, who defines the constraints for navigation and the appropriate input/output devices for interaction.

Nature is framed in a different way to people or things. One critical feature in nature is the horizon. With no horizon as a reference point, everything becomes relative and

subject to varying interpretations. Individuals are not framed in the same way as crowds; and sub-elements of scene may appear in various sub-frames. Doors, windows, mirrors, etc. are all frames in frames. In this dovetailing of frames the various parts of the set are not only separated, but may also be seen to converge.

This multiplicity of sub-frames means that the set itself is no longer the object of geometric divisions, but of physical gradations. Ultimately, the film is projected onto a screen which becomes the ultimate frame of frames. In desktop virtual environments the computer screen is the ultimate frame and in immersive virtual environments as well, the field of view of a head mounted display is such that there always exist a certain frame around the display.

The frame is related to the angle of framing. This is because the closed set is itself an optical system which refers to a point of view on the set of parts. These points of view may be extraordinary in real life but, in the film, must appear to be normal and regular - either from the point of view of a more comprehensive set which includes the first, or from the point of view of an initially unseen, not given, element of the first set.

Space is no longer a particular, determined space, it has become any-space-whatsoever. Any-space-whatsoever is not an abstract universal, in all times, in all places. It is a singular space which has merely lost its homogeneity. That is, it has no principal of metric relations or connections between its parts. Linkages may be made in an infinite number of ways. It is a space of virtual conjunction, grasped as pure locus of the possible. What in fact manifests the instability, the heterogeneity, the absence of fixed links in such a space, is the richness in potentials or singularities which are, as it were, prior conditions of all actualisations, all determination.

5. The Components of an Image in Virtual Environments

Continuing this argument, we suggest that the design of a virtual environment may be seen as the act of framing or in other words the determination of a closed system which includes all elements which are present in the image. The “props” consist of the “solid” objects which define the spatial elements in a virtual environment. The “sets” are comprised of the “void” spatial elements in the virtual environment and the characters are the dynamic, animated objects inhabiting the virtual environment.

5.1 PROPS

As is the case in real environments, we survive by orienting ourselves to objects which are distributed in space and which allow for the spatial experience. Similarly a virtual environment consists of visual and auditory objects which bind and subsequently define space. Props are these inanimate objects which define space in a virtual environment, by means of their arrangement. Props may be “landmark” objects (see figure 2), which

mainly function as a point of reference and cannot be entered, or "binding" objects, which generally define space (as distinct from void) by binding it in some way.

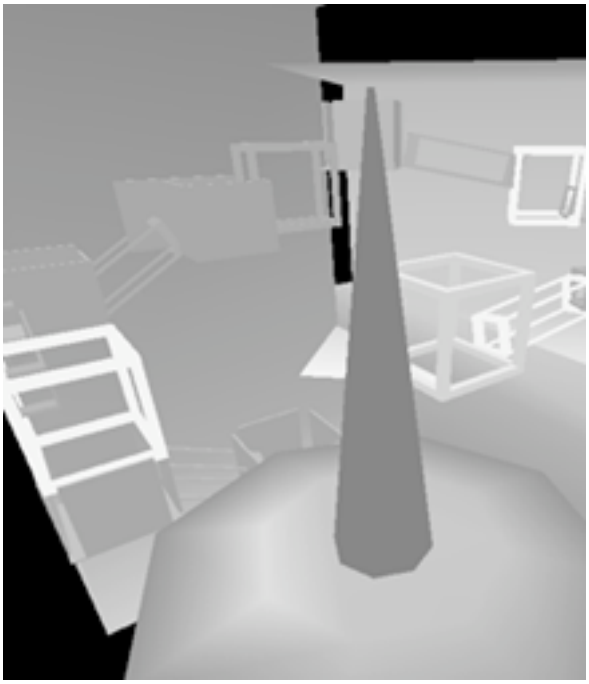

Figure 2. Landmark object

Lynch (1960, p.48) has defined landmarks as point-references within the urban environment which may vary widely in scale. Their use involves the singling out of one element from a host of alternate possibilities. They are frequently used clues of identity and even of structure. Some landmarks are distant and can be used as radial references whilst others symbolize a constant direction. To a certain extent, they may even be mobile if their motion is sufficiently slow and regular, but in this case they may be included in the characters category of elements.

When designing landmarks within urban environments, it is important to know the principle criteria which affect their significance within the context and scale of the environment. When designing a navigable virtual environment, these criteria must be adapted to the intrinsic characteristics of the virtual environment. Following Lynch (1960) and Appleyard (1969), this paper suggests that the following aspects of landmarks contribute to their significance within the context of a virtual environment:

- *Form*. If an object has prominent physical features (sharp contours, clear form, bright surfaces) or definite size disparities between itself and the environment then it more easily influences memory. This is due to its

ability to be singled out from a multitude of other possibilities by virtue of its formal qualities.

- *Function* and *Association*. If an object has a high usage or performs a symbolic function, or if for example there is an activity, sign or history associated with it, it may signify a landmark.
- *Location*. If the object is located at an intersection (where path decisions are made), especially in a smaller scale context, then we would associate it as a clear landmark. Smyth et al. (1994, p.312) elaborated on this by concluding that landmarks become positioned in space when they are crossed by many routes, therefore becoming a major part of the organizational framework for the map of the environment.

Essentially, the object should be visible from many locations and also contrast with its background. This "figure-background" contrast does not necessarily refer to the physical characteristics of the landmark, but to any of its characteristics (age, style, etc.), therefore overlapping with the functional and formal aspects.

5.2 SETS

An attempt is made here to suggest a taxonomy of the generic elements of space in virtual environments, which are considered and analysed in terms of their spatial qualities and significance and of the effect they may have on the operator's wayfinding behaviour. These elements together constitute the sets that the virtual environment consists of. They may either be: places, paths, domains or thresholds.

- A *place* is a space where particular activities are carried out. More specifically, a place implies static action taking place within its boundaries. When its boundaries are well defined and the relation between "inside" and "outside" is also clearly defined then the operator may feel safe and secure to engage into an activity in the specific place. A place may be a goal, or a focus for an event or a point of departure towards the rest of the environment. (Norberg-Schulz, 1971, p.20). (See Figure 3).
- A *path* is a kind of space which implies movement, that is dynamic action, and within which directions are always evident, due to the formal qualities of its spatial arrangement. A path consists of a starting point, a direction to be followed through a sequence of places and events and finally a destination. (See Figure 4).
- A *domain* is a subset of the whole environment which consists of a system of paths and places. Domains are mainly thought of rather than experienced, since we cannot directly experience them as a whole. It is necessary to structure an environment by means of domains, in order to be able to conceptualise it as a whole. In real environments, domains (or *districts* as Lynch (1960) has named them) expand in two dimensions, due to physical constraints. In virtual environments, which are devoid of such constraints, domains may expand in three dimensions.

- *A threshold is an* intermediate space which functions as interface or intersection between the other spatial elements. The nature of this interface may range from a state where one space flows into the other to a case where one space clearly ends and the other begins.

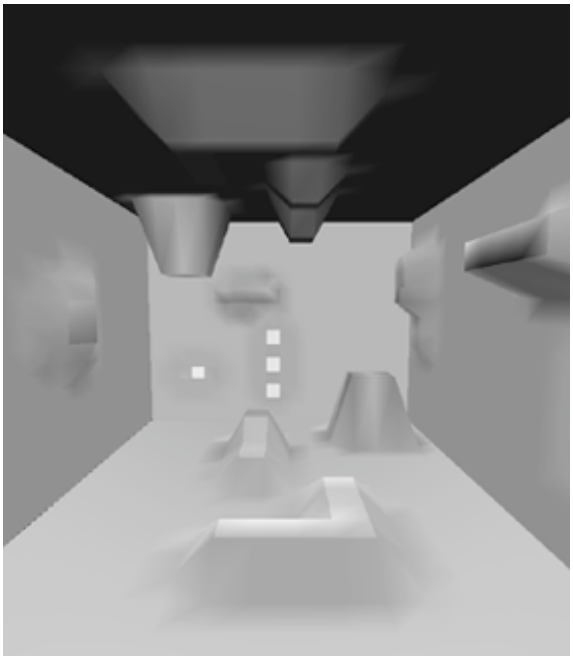

Figure 3. A Place

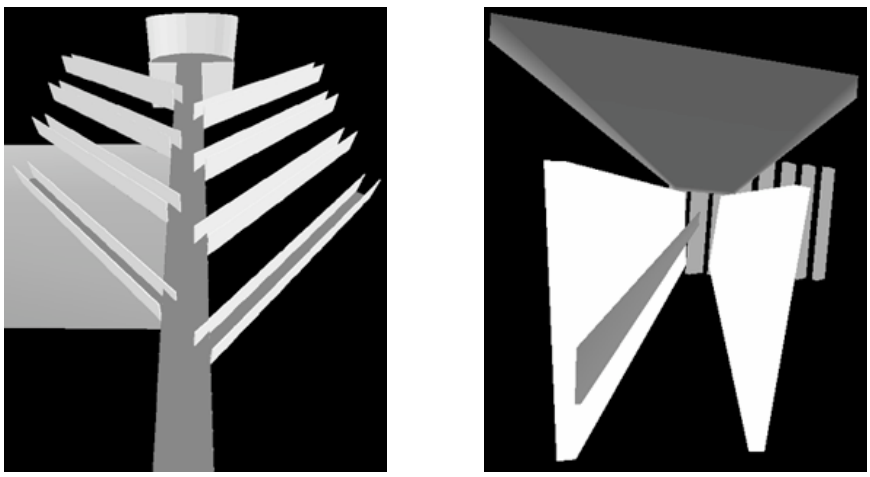

Figure 4. Two examples of Paths

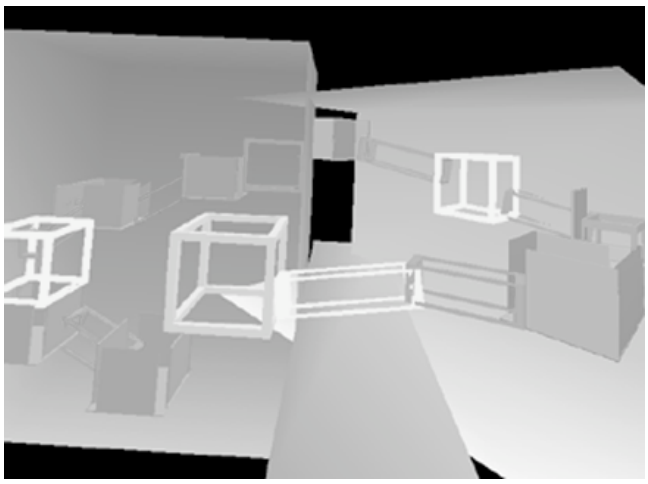

Figure 5. A Domain

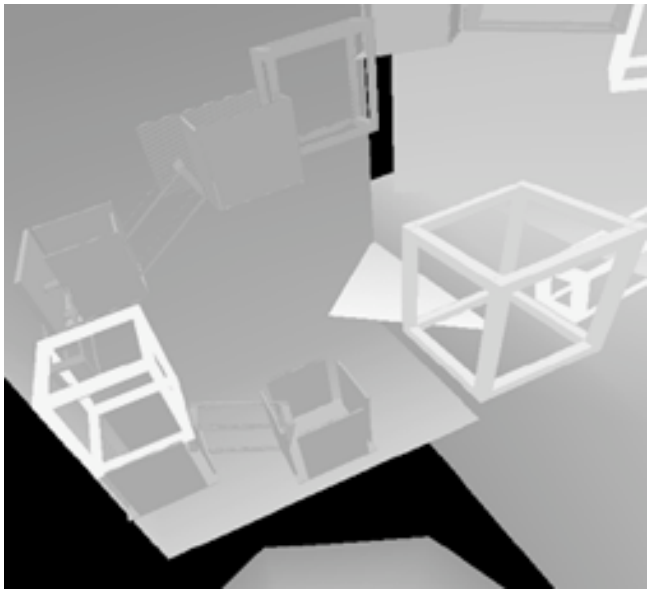

Figure 6. Thresholds

Norberg-Schulz (1971, p.29-30) quotes Lynch (1960) on the fact that the generation of an informative image or cognitive map of the environment is facilitated by the design of distinct and unforgettable places or nodes, paths with a clear end and districts with a particular character.

Thresholds, although void spatial entities, may also establish space in that they partly bind and subsequently define spatial elements, such as paths or places: they designate a gate from a space and an exit to another space. They are the intersections of the possible routes of an operator within the environment. Thresholds afford views to more than one space and involve decision-making (where to go next). The combination of the actual or potential navigation choices and the greater complexity of the scene, coupled with the decision-making process (Gale et al., 1990, p.21) and the action of passing through a threshold make them the foci of route knowledge. When an operator is acquiring spatial knowledge through navigation, more information is being registered in thresholds, than in spaces between them. Thresholds are significant for the action of navigating in a virtual environment, since important decisions for wayfinding are taken there. Therefore, they have to be carefully designed so as to aid the operator's overall spatial awareness.

5.3 CHARACTERS

Characters are dynamic, animated objects. They may exhibit a certain behaviour, or may move within the virtual environment, or respond to an action of the user. They may also have intelligence.

6. The Form of Spatial Elements and its Significance for the Operator

Spaces may be defined implicitly or explicitly. Thiel (1961) classifies spaces by their degree of spatial definition as

- vagues - spaces vaguely defined by objects in a random or statistical distribution. Vagues are of an indefinite and ambiguous form.
- spaces - areas of intermediate degree of explicitness, more or less implicitly suggested and of a fluctuating quality.
- volumes - explicit, completely defined spaces resulting from the use of complete and contiguous surfaces in all positions.

The quantity of space-establishing elements 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 generally more important. Spaces and Volumes have a perceptible form and according to this form they imply a particular response from the operator.

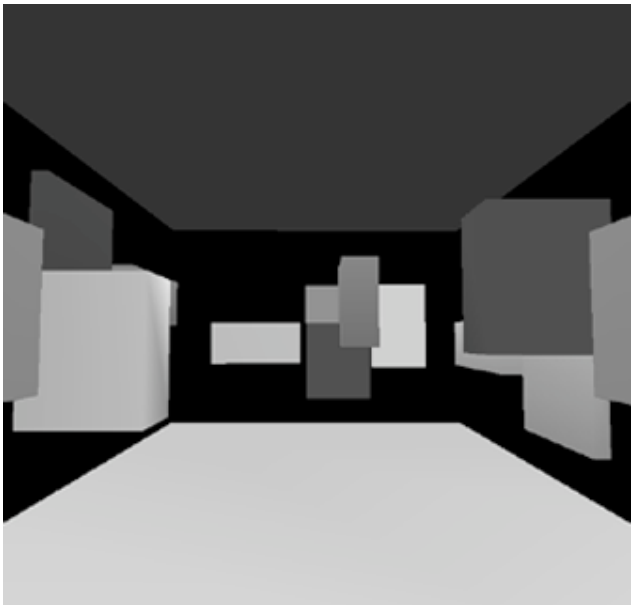

Figure 7. A Vague

The form of a place, of course, affects the way that we experience it. "A place that is being experienced as an 'inside' should generate a spatial sense of proximity, centralisation and closure." (Norberg-Schulz, 1971, p.20). The properties of the enclosure (dimensions, shape, configuration, surfaces, edges, openings) determine the qualities of the place (form, proportion, scale, definition, colour, texture) (Ching, 1979, p.175) and accordingly how we experience it. A centralised form means concentration and results in limiting the size of a place.

A space or volume which has any one overall dimension two or more times greater than any other dimension is called a run. This type of space implies dynamic action, that is movement, and is likely to be a path of some sort (horizontal or vertical). The rest of the spaces are named by Thiel as areas, and following the above taxonomy are likely to be places, if they are clearly defined by means of binding objects. Such spaces imply static action generally relating to a centre or the periphery of their spatial configuration.

Referring to this distinction of form quality, Keppes (as quoted in Thiel, 1961, p.41) suggests that our environments mainly consist of configurations which may be seen as either patterns of a static character, with order, closure, a tendency towards a centre, cohesion and balance or, alternatively, patterns of a dynamic character, exhibiting mobility, freedom, change and opening. These characteristics may be recognised in almost every pattern emanating from real-world visual sensory stimuli and we become

aware of them as a result of the effect they have on our motivations, feelings and states of mind.

Similarly, Norberg-Schulz (1971, p.26) mentions this distinction as the basic dichotomy between the concepts of place and path which 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." Quite often the loci of tension between centralisation and longitudinality are thresholds.

7. Conclusion

The guidelines outlined in this paper are presented as hypotheses. The next stage of this project is the evaluation of the effectiveness of the guidelines. This will be done by practical experimentation.

A virtual environment functioning as a three-dimensional interface to a repository of images and sounds has been designed following the guidelines suggested by this paper. User feedback will indicate whether the way that space in this virtual environment has been designed does inform operators sufficiently for them to navigate within this representation of data sets. Aspects of preliminary models for this virtual environment are presented here to give a visual indication of the generic elements of space in such an environment.

8. References

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

Bridges, A.H. and Charitos, D. (1996) On Architectural Design in Virtual Environments, Proceedings of the 2nd Creativity and Cognition International Symposium, Candy, L. And Edmonds, E. (eds), Loughborough University, April 96, 184-192.

Bryson, S. (1994) Approaches to the Successful Design and Implementation of VR Applications, Proceedings of the Virtual Reality Applications Conference, June 94, British Computer Society, Leeds.

Charitos, D. and Rutherford, P.(1996) Guidelines for the Design and Exploration of Virtual Environments, Proceedings of the 3rd UK Virtual Reality Special Interest Group Conference, July 96, De Montfort University, Leicester, 93-111.

Charitos D. and Rutherford, P. (1997) Ways of Aiding Navigation in VRML Worlds, Proceedings of the 6th International EuropIA Conference, Coyne, R., Ramscar, M.,Lee J. and Zreik, K. (eds), April 97, Edinburgh, 119-132.

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

Darken, R.P. and Sibert, J.L. (1993) A Toolset for Navigation in Virtual Environments, Proceedings of ACM User Interface Software and Technology 1993, 157-165.

Deleuze, G. (1983) Cinema 1, L 'Image-Mouvement, Les Editions de Minuit, Paris, translated by Hugh Tomlinson and Barbara Habberjam as 'Cinema 1:The Movement Image', Athlone Press, London, 1986.

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

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

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

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

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

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

World Design Inc. (1993) 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 93.

ALAN BRIDGES and DIMITRIOS CHARITOS
(a.h.bridges@strath.ac.uk, D.Charitos@strath.ac.uk)
University of Strathclyde
Department of Architecture and Building Science
131, Rottenrow
Glasgow G4 ONG
Scotland