On architectural design in virtual environments

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This paper considers the domains of architectural design and film theory for the purpose of informing the design of virtual environments (VEs). It is suggested that these domains may form a background for the consideration of possible metaphors for the design of VEs. Firstly, the paper investigates the relation between architecture and virtual reality technology, through the nature of drawings and virtual environments as means of representing three-dimensional spaces. Then, differences between VEs and physical environments (PEs) are identified for the purpose of understanding the intrinsic nature of VEs, by comparing them to our familiar everyday spatial experience. This step is considered essential in helping us understand how we might be able to develop an architectural conception of designing spaces, in the context of VEs. The paper then presents two directions towards informing VE design by means of theoretical and practical architectural design knowledge. Finally, the use of film-related studies is considered as a means of enhancing our conception of time and movement in VEs. © 1997 Elsevier Science Ltd.

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Computer drafting and drawing in general play a major, if not entirely decisive, role in the creation and development of architectural ideas. Drawing has provided a way for architects to explore their concepts about built form, free from the constraints of construction. The power of drawings lies as much in their power of suggestion as in their power of description. Evans[1] has pointed out that 'Recognition of the drawing's power as a medium turns out, unexpectedly, to be recognition of the drawing's distinctness from and unlikeness to the thing that is represented, rather than its likeness to it, which is neither as paradoxical nor as dissociative as it may seem'. Certainly for a particular group of architects (Daniel Libeskind, Lebbeus Woods, Wolf Prix, Zaha Hadid and others) the drawing is almost more important than the building for it is only relatively recently that these architects have been commissioned to build.

1 **Evans, R** *Translations from drawings to buildings*, AA Files 12, Summer 1986, pp 3–18

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Libeskind[2] elaborates on how drawings have assumed the identity of signs. They are now considered to have an existence of their own. Indeed, they may be seen as the major output of architectural design. Once the idea of a drawing as an instruction for building is dispensed with, drawings may be seen as a coherent formal system in themselves. Drawings may thus exist as independent systems without any reliance on the potential existence of any building. They have their own coherent set of rules and conventions and, furthermore, can carry meaning and serve as subjects for interpretation.

Drawings are abstract representations of designed environments and so may be considered a subset of the class of virtual environments (VEs), in the sense that they both are simulations of mental models of environments conceived by the designer. VEs, however, may also be directly experienced as three-dimensional spaces, due to the enabling technologies which support them. As such, they may serve as an alternative platform for design exploration. The advent of related technologies has led Baudrillard[3] to argue that 'Abstraction today is no longer that of the map, the double, the mirror or the concept. Simulation is no longer that of a territory, a referential being or a substance. It is the generation by models of a real without origin or reality: a hyperreal'. VEs can accordingly be seen as 'hyperrealities' carrying experiential qualities, existing independently in their own right and not necessarily as simulations of real objects and phenomena which constitute PEs.

A VE does not necessarily need to imitate any reality, as in the case of a simulation of a real-world task. It may communicate to the operator a synthetic experience which cannot happen in the real world. This is due to the fact that a VE is being experienced via the same perceptual processes that are employed for perception in the real world, so if the patterns of information, which are being perceived are accurately constructed to simulate the perceptual mechanisms inherent in the subject, a nonrealistic synthetic environment still comes across as convincing and effective for a specific task[4]. In this paper, the relationship of architecture and VE design is investigated from this viewpoint.

1 Architecture and virtual reality

There is a two-way relationship between architectural design and virtual reality technology

- Architectural design can employ virtual reality techniques for evaluation, communication and documentation purposes
- Virtual reality can employ architectural design, as one of the disciplines, which may contribute to the design of virtual environments.

2 Libeskind, D *Countersign,* Architectural Monograph no. 16, Academy Editions, London (1991)
3 Baudrillard, J *Simulations* Semiotext(e), New York (1983)
4 Carr, K and England, R *Simulated and virtual realities: elements of perception* Taylor and Francis, London (1995) p 6

This paper focuses on the latter aspect of this relationship.
Gasee[5] has defined the interface as: 'the cognitive locus of human–computer interaction' . . . Humans participate in online networked communities (MUDs, MUSEs) and interact with computers via human–computer interfaces (HCIs), in ways that give the interaction experience a predominant three-dimensional spatial character.

In graphics user interfaces (GUIs) the screen can be seen as the barrier between the users and the 'world' of the computer which they are trying to explore. The same can be said about cinema and since the beginning of the century filmmakers have been trying to find ways to engage the viewer and surpass this barrier. Walker[6] suggested that VR technology takes us to the next generation of human–computer interfaces, where the user can surpass the screen and 'enter' the computer. He defines 'a cyberspace system as one that provides users a three-dimensional interaction experience that includes the illusion they are inside a world rather than observing an image'.

These developments contribute to the notion of the HCI as having a three-dimensional spatial character. More so a virtual environment, by definition, is experienced by the user as a kind of three-dimensional space.

Whenever we need to represent, dynamically and visually, a task by employing some type of metaphor (not intrinsic to the nature of the task) we may design a VE which comprises several spatial entities and events, which have no real-world counterparts. These entities and events accommodate human activities such as navigation, interaction and communication. To this extent, the design of a VE is an architectural problem as well, so it may benefit from making use of architectural design knowledge.

2 *The differences between VEs and PEs*

VEs and PEs may be similar in the way that they are being manifested to the human, because they are being experienced via the same perceptual processes employed for perception in the real world, but are significantly different by nature. Since we have lived and evolved in physical environments, we know them and understand their nature. By identifying the differences between PEs and VEs, we may begin to understand the nature of virtual environments. These differences may be seen as problems which are due to the limitations of current VR technology and which may be overcome as the technology evolves; particular emphasis is given here to the significance of representing the human body within the VE. These differences may also be seen as intrinsic characteristics of VEs, causally related to VR technology again, but essential in helping us understand the individual nature of VEs as a medium.

5 **Gassee J L** 'The evolution of thinking tools' in *The art of human-computer interface design*, **Laurel, B** (ed), Addison-Wesley, Reading, MA (1990) p 226
6 **Walker, J** 'Through the looking glass', *The art of human-computer interface design*, **Laurel, B** (ed), Addison-Wesley, Reading, MA (1990) p 444

2.1 Limitations of VEs

Due to such limitations of current VR technology, the character of a spatial experience provided by a VE is far from realistic

- VE systems cannot approach the resolution and complexity of experiencing a PE
- Output devices provide feedback (visual, auditory, tactile) for only three of the five senses
- Users do not receive enough visual, auditory or tactile kinesthetic information from the representation of their bodies in the VE.

2.1.1 The human body and its avatar

In reality, one sees the environment not only with the eyes but with the help of a system consisting of the eyes, which are positioned in the head, which is positioned on the body, which is resting on the ground. An observer perceives the position of 'here' as being relative to the environment and also to the body which is 'here'. The occupied point of observation is constantly in motion, so observers always see their bodies moving relative to the ground or see that part of the environment toward which they are moving. These are all cases of visual kinesthesis[7]. Humans have evolved while perceiving themselves as parts of the environment and have accordingly developed space schemata for existing in this environment. McLellan[8] describes '*avatars*' as the only representations of the operators' bodies, which are displayed to them in an immersive VE. If the avatar is only a three-dimensional cursor or a glove, as is often the case, operators cannot perceive the 'here' and 'there' of the surrounding environment as relative to their body being 'here', and this reduces their sense of presence. They do not receive the visual feedback needed for informing them of their own movements relative to the VE. There is experimental evidence[9] which suggests that the coupling between our own movements and shifts in the optic flow allows us to estimate where things are in space relative to ourselves and this coupling causes a sense of telepresence. The sense of presence in a VE[10] increases when there is a direct visual consequence of each of the operator's movements and when there is an obvious mapping between the operator's movements and the movements of the virtual body. There is experimental evidence showing that kinesthetic sense, which includes proprioception, is just as important as the increasing quality of the visual and auditory channels for increasing the sense of presence and for this reason the representation of the body in the VE is an essential feature of the system.

The avatars used as representations of the operators' bodies in VEs do not provide them with the visual kinesthetic feedback needed for informing

7 **Gibson, J J** *The ecological approach to visual perception* Lawrence Erlbaum Associates, London, 1986 (first published 1979), pp 205–208

8 **McLellan, H** 'Beam me up to my avatar', in *VR World*, Mecklermedia, March/April 1994, pp 33–35

9 **Smets, G J F, Stappers, P J, Overbeeke, K J and van der Mast, C** 'Designing in virtual reality: perception-action coupling and affordances', in Reference 4, p 196

10 **Steed, A, Slater M and Usoh, M** 'Presence in immersive virtual environments', *Proceedings of the 1st UK VR-SIG Conference*, Nottingham, March 1994

them of their constantly changing position in the environment. Consequently, their sense of presence and their overall sense of space is limited.

2.2 Characteristics of VEs

The differences between VEs and PEs may also be seen as intrinsic characteristics of VEs which are essential in helping us understand the nature of VEs as a medium

- There are no physical constraints to dictate the dynamic, spatiotemporal nature of a VE; one cannot speak of gravity or friction in a VE unless we design and implement them. Although all geometrical models of objects are designed in three-dimensional Cartesian space, we are not limited to three dimensions in a VE, because any 2D plane or point may unfold to reveal other environments. VEs also allow for the interactive visualization of data sets represented by 4D or higher-dimensional spaces[11,12].
- There is no scale consistency. The scale of the environment, relative to the operator, may be altered at will. We may transform our size in relation to each level of the environment[13] from a geographical level to the level of the smallest thing, and this way experience all levels in a very direct way, as we can experience the level of things in PEs.
- Space is noncontiguous, multidimensional and self-reflexive; the structure of spaces within a VE may be more of a hypertextual nature. In general, the principles of real space may be violated in VEs[14] and the characteristics and constraints are only determined by the specifications which define the VE.
- Time is not necessarily continuous and its pace may be altered (slowed-down or speeded-up).

3 Learning from architecture

Taking into account the above mentioned differences between VEs and PEs, this paper presents ways of selectively applying architectural knowledge towards informing VE design. Two directions for doing so are suggested here.

3.1 Learning from architectural theory

We may learn from architectural and environmental design theory by attempting to introduce a taxonomy of the elements that a VE consists of, with respect to the subjective spatial experience of the user of this VE. This taxonomy is based on Norberg-Schulz's[15] writings about existential space, as well as urban space taxonomies[16-18].

11 Feiner, S and Beshers, C 'Visualizing *n*-dimensional virtual worlds with *n*-vision', *Computer Graphics*, Vol 24 No 2 (1990) 37–38

12 Novak, M 'A cyberspace chamber of the 4th dimension', *The redoubling of space in relation to architecture and urbanism seminar*, Technische Universiteit Delft, Delft, The Netherlands, December 1994

13 Charitos, D 'Defining existential space in virtual environments', *Proceedings of the Virtual Reality World '96 Conference*, IDG Magazines, Stuttgart, February 1996

14 Benedikt, M 'Cyberspace: some proposals', *Cyberspace, first steps* **Benedikt M** (ed), MIT Press, London (1991) pp 119–224

15 Norberg-Schulz, C *Existence, space and architecture* Praeger Ltd, New York (1971)

16 Lynch, K *The image of the city* MIT Press, Cambridge, MA (1960)

17 Thiel, P 'A sequence-experience notation', *Town Planning Review* Vol 32, April 1961

18 Mitropoulos, E G 'Space networks: toward hodological space design for urban man', *Ekistics*, No 232, March 1975, 199–207

According to this taxonomy the elements that a VE comprises of are

a) Places are the spaces where activities are carried out and these particular activities are only meaningful in relation to these places. A place may either be a *point of departure*, a *focus for an activity* or a *goal*. The topological relations of 'inside' and 'outside' of a place should be clearly defined if the designer wants the experience of being in this place to come across as meaningful and convincing for the user. This relation is established by appropriately designing the boundaries which delimit a place. Having defined this relation, the user may identify with the place and feel 'secure' enough to engage in an activity.
b) A path is a kind of space which expresses a tendency towards mobility and expansion and within which directions are evident, due to its formal qualities. A path consists of

- a starting point
- a direction to be followed through a sequence of places and events
- the final goal.

Lynch[16] has suggested that subjects move through the city following a sequence, facilitated by anticipation of memorable events, details and points of reference, which trigger specific moves for navigation. These events and places which one experiences on the way during moving along a path, determine the character of the path.

c) Places usually relate to several directions by a system of paths and these paths express a subject's possibilities for movement and divide the environment into, more or less well defined areas, which we call 'domains'. We are structuring an environment into domains by means of paths and places, so that we can 'take possession of the environment', as in Schulz's expression[15]. The domain can therefore be defined as a relatively unstructured 'ground', on which places and paths appear as more 'pronounced' figures. Domains are conceived as having a two-dimensional extent, which the observer can mentally go inside.
d) A threshold is the locus of interaction between any spatial elements of the VE. In these spaces, tension between the diverse spatial character of the interacting elements affects the behaviour of the operator who happens to be in them. Examples of thresholds are: the meeting point between two paths or between a path and a place or all kinds of openings.
e) Space-establishing elements: in accordance with the terminology of programming languages used for the design and development of VEs, we may refer to all the elements which establish space in a VE as 'objects'.

With respect to their form, these could be classified as

- Surfaces or planar objects
- Objects, when their form is clearly three-dimensional.

According to their function, space establishing elements are either

- Bounding objects or edges, a more generic term than the one used by Lynch, which define all elements of existential space by suggesting a spatial form out of the void, in varying degrees of explicitness
- Objects which function more like points of reference or as landmarks and generally communicate some meaning to the operator.

All objects in a VE can either be still or animated. The overall impact of the object for the VE and the interaction process is determined by

- Its position in space, geometry, colour, texture and other characteristics of the object's appearance: Benedikt refers to these attributes as extrinsic and intrinsic dimensions[19]
- The degree of interactivity that it affords the operator
- Its autonomous behaviour or intelligence
- Its possible evolutionary nature[20].

3.2 Learning from architectural expertise

Architectural expertise is suitable for giving answers to the problem of how to compose form in order to accommodate function and convey meaning. Such expertise may be selectively used when designing three-dimensional entities in VEs, for the purpose of representing abstract data or events. It is essential, however, that the intrinsic characteristics of VEs are taken into account, when doing so.

For example, an opening (door or window) should exist in VEs only when the wall, it is situated on, does not permit the passage through its surface; that is only when collision detection is supported. This gives a meaningful and consistent identity to an opening. If we were able to enter a space by passing through a wall then a door existing on this wall would lose its significance. These facts influence not only the opening itself but the relation of the enclosed space, through the direction directed by the door, to the outside and vice versa. The 'portal' is a special kind of opening, specific to VEs, which enables noncontinuous movement between remote spaces within the VE. Teleportation may simplify navigation but may also prove disorientating as it corresponds to gaps in the cognitive maps generated by operators. Therefore, portals should be very carefully designed and integrated within the environment and signified accordingly by formal elements. Such consistencies help operators establish an existential foothold in a VE, because they correspond to familiar space schemata and real-world actions.

19 Reference 14, p 134
20 Fraser, J *An evolutionary architecture* Architectural Association, London (1995)

Objects designed as elements of a VE do not necessarily have to imitate the forms that objects of our real-world possess (columns, roofs, trees, mountains), unless there is a functional purpose for these forms to exist, as in the case of communicating some specific meaning. In the real world, forms of structural elements are usually designed so as to visually express their structural character, which is determined by physical constraints. In VEs, simulated physical constraints like gravity or friction do not necessarily affect the form of an object in any way. They are only implemented for the purpose of making interaction with the VE seem more realistic. Qualities of built structures in a PE, such as the materials, thickness and weight of structural or other built elements, have no significance in VEs. Designers should try to abstract the forms of objects in VEs and explore the expressive potential of form, which is not dictated by any kind of constraint. Formal detail should be added only when it serves some purpose. Elements which carry meaning or express affordances to the operator can be clearly distinguished within the context of a VE, which is not cluttered with unintended formal detail.

If we want a VE to come across as meaningful and convincing, we should design it so that it helps operators feel comfortable to engage in actions there. Topological relations of 'inside' and 'outside' should be clearly defined, so that the users' experiences and memories are located, and the inside of space becomes the inside of their personality[21].

4 Learning from film-related studies

Since the late 19th century, film has provided a platform for spatial experimentation. Gance[22] expressed the hope that cinema would be a 'sixth art' which would provide 'synthesis of the movement of time and place'.

4.1 Cineplastics

It was the art historian Faure, however, who first coined a term for the cinematic aesthetic that brought the two dimensions together 'cineplastics'. 'The cinema', he wrote in 1922, 'is first of all plastic. It represents, in some way, an architecture in movement that should be in constant accord, in dynamically pursued equilibrium, with the setting and landscapes within which it rises and falls . . . The cinema incorporates time to space. Better, time, through this, really becomes a dimension of space'[23].

By means of the cinema, Faure claimed, time becomes a veritable instrument of space, 'unrolling under our eyes its successive volumes ceaselessly returned to us in dimensions that allow us to grasp their extent in surface and depth'. The 'hitherto unknown plastic pleasures' thereby discovered would, finally, create a new kind of architectural space, akin to that imagin-

21 Bachelard, G *La poétique de l'espace* (The poetics of space, originally published in 1957) as translated in Greek by Veltsou, E and Hatzinikoli, I. Ekdosis Hatzinikoli, Athens, 1982, ch IX

22 Gance, A 'Qu'est-ce que le cinimatographe? Un sixiheme art', *Cini-Journal* 195, No 9, March 1912, reprinted in **M L'Herbier** *L'Intelligence du cinimatographe*, Editions Coria, Paris (1946) p 92

23 Faure, E 'De la ciniplastique in L'Abre d'Eden', Editions Crhs, Paris (1922) reprinted in **M L'Herbier** *L'Intelligence du cinimatographe* Editions Coria, Paris (1946) p 268 ary space 'within the walls of the brain'. 'The notion of duration entering as a constitutive element into the notion of space, we will easily imagine an art of cineplastics blossoming that would be no more than an ideal architecture, and where the "cinemimic" will . . . disappear, because only a great artist could build edifices that constitute themselves again ceaselessly by imperceptible passages of tones and modeling that will themselves be architecture at every instant, without our being able to grasp the thousandth part of a second in which the transition takes place'.

4.2 Cinematic time and movement

One of the most striking preoccupations of modernist and postmodernist aesthetics is the question of time. Bergson[24] puts forward several theses on movement and time, which are of relevance to virtual worlds. The first (and best known) is that movement is distinct from the space covered. Space covered is past whereas movement is present—the act of covering. The space covered is divisible whilst movement is indivisible. This leads to the proposition that the spaces covered all belong to a single, homogeneous space, whilst the movements are heterogeneous, irreducible amongst themselves. Thus movement cannot be reconstituted with positions in space or instants in time. If we examine a sequence of film stills we see a succession of 'frozen instants' but the movement always takes place in the intervals between. Movement thus always occurs in a concrete duration and each movement has its own qualitative duration.

Deleuze[25] has commented that modern science has related movement not to privileged instants but to any-instant-whatever. Bergson[26] remarked that 'Modern science must be defined pre-eminently by its aspiration to take time as an independent variable.' Cinema simply follows this lineage. Deleuze[27] thus defined cinema as the system which reproduces movement as a function of any-instant-whatever, that is, as a function of equidistant instants, selected so as to create an impression of continuity. The relevance to virtual worlds becomes apparent if we consider the 'intermediary' form of animated film (cartoons). If the cartoon belongs to the cinema, this is because the drawing no longer constitutes a pose or completed figure, but the description of a figure which is always in the process of being formed or dissolving through the movement of lines and points taken at any-instants-whatever of their course. The cartoon film is related not to an Euclidean, but to a Cartesian geometry. It does not give us a figure described in a unique moment, but the continuity of the movement which describes the figure. Writing around the same time as Faure, Panofsky[28] asserted 'these unique and specific possibilities' of film could be 'defined as dynamatisation of space and, accordingly, spatialisation of time. . . . Not only bodies move in space, but space itself does, approaching, receding,

24 Bergson, H *L'Evolution créatrice* Presses Universitaires de France, Paris (1907) [Transl. A Mitchell *Creative evolution*, Macmillan, London (1912)]
25 Deleuze, G *Cinema 1, L'Image-Mouvement*, Les Editions de Minuit, Paris 1983 [Transl. H Tomlinson and B Habberjam *Cinema 1: the Movement-Image* Athlone Press, London (1986)]
26 Reference 24, p 355
27 Reference 25, p 5
28 Panofsky, E *Die Perspektive als 'symbolische Form'*, Vorträge der Bibliothek Warburg, 1924–25 (Leipzig and Berlin, 1927: 258–330) [Transl. C S Wood as *Perspective as symbolic form*, Zone Books, New York (1991)]

turning, dissolving and recrystallising as it appears through the controlled locomotion and focusing of the camera and through the cutting and editing of the various shots'. This led to the inevitable conclusion that the proper medium of the cinema was not the idealization of reality, as in other arts, but physical reality as such.

The elements of cinema relate to VEs insofar as they operate within a closed system. Following Deleuze[29] again, we will call the determination of a closed system, a relatively closed system which includes everything which is present in the image—sets, characters and props—*framing*. Framing is the art of choosing the parts of all kinds which become part of a set. The closed system determined by the frame can be considered in relation to the data that it communicates to the spectators: it is 'informatic' and saturated or rarefied. Considered in itself and as limitation, it is geometric or dynamic-physical. It is an optical system when it is considered in relation to the point of view, to the angle of framing. Finally, it determines an out-of-field, sometimes in the form of a larger set which extends it, sometimes in the form of a whole into which it is integrated.

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: it is the relationship between parts and it is the state of the whole. The purest form of this kineticism may be seen in the Expressionist films of the 1920s, such as Robert Wiene's *Das Kabinett des Dr. Caligari* (1920) and *Raskolnikov* (1923), or Wegener's *Der Golem* (1920), whose great set designs would not look out of place today. Geometry was emancipated from the coordinates which condition the extensive quantity and form the metrical relationships which regulated movement in homogenous space.

5 *Conclusions*

Virtual environments should not attempt to model the 'real' world in ever increasing detail (like Borges' map makers who drew maps at greater and greater levels of detail until they finally produced a map which fitted exactly over the real space). A VE does not necessarily need to imitate any reality, as in the case of a simulation of a real-world task. It may communicate to the operator a synthetic experience which cannot happen in the real world, constituting a 'hyperreality', existing independently in its own right.

Designing a VE means designing spatial entities which accommodate human activities such as navigation, interaction and communication. To this extent, the design of a VE is an architectural problem as well, so

29 Reference 25, p 18

it may benefit from making use of architectural design knowledge. Such knowledge can inform the way we face the problem of creating forms of objects in VEs and composing them so as to produce functional and meaningful spaces. However, since architectural design refers to PEs, we have to take into account the differences between VEs and PEs, if we are to adapt architectural knowledge to the design of VEs. Even though VEs and PEs are experienced by humans via the same perceptual processes employed for perception in the real world, they are still different by nature. These differences may be seen as problems, which are due to the limitations of current VR technology. They may also be seen as intrinsic characteristics of VEs, essential in helping us to understand the individual nature of VEs as a medium.

The limitations of current VR systems in terms of providing a realistic experience are

- Poor resolution and lack of complexity in the simulated experience
- Feedback provided for only three of the five senses
- Users do not receive enough visual, auditory or tactile kinesthetic information from their 'avatars' in the VE and as a result their sense of presence and their overall sense of space is limited.

Defining intrinsic characteristics of VEs is essential in helping us understand the nature of VEs as a medium. In VEs

- There exist no physical constraints unless we design and implement them
- There is no scale consistency, since the scale of the environment, relative to the operator, may be altered at will
- Space is noncontiguous, multidimensional and self-reflexive
- Time is not necessarily continuous and its pace may be altered.

Taking into account the differences between VEs and PEs, architectural knowledge can be selectively applied for the purpose of informing VE design. Firstly, we may learn from architectural and environmental design theory. Based on such literature, this paper introduces a taxonomy of the elements that a VE consists of

- Places
- Paths
- Domains
- Thresholds.

These spatial elements are established by objects, which may be accordingly classified in terms of their form and function in the VE.

Secondly, we may selectively learn from architectural expertise in terms of composing form in order to accommodate function and convey meaning in VEs. However, functionality has a different significance in VEs and form is not dictated by any physical constraints, so it is clear that architectural expertise, which explicitly refers to PEs, has to be carefully adapted to the intrinsic characteristics of VEs.

The medium of cinema has provided this century's philosophers with a context for rethinking the concepts of movement and time. Such readings may also prove valuable for enhancing our understanding of movement and time in the context of VEs.