DIGITAL ARCHITECTURE AS THE EXTENSION OF PHYSICAL SPACES: ASYMPTOTE'S NEW YORK STOCK EXCHANGE VIRTUAL REALITY ENVIRONMENT

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

HALİL AYOĞLU

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF ARCHITECTURE

JANUARY 2005

Approval of the Graduate School of Natural and Applied Sciences

_____

Prof. Dr. Canan Özgen
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Architecture.

_____

Assoc. Prof. Dr. Selahattin Önür
Head of Department

This is to certify that we had read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Architecture.

Asst. Prof. Dr. Berin F. Gür Co-supervisor	Asst. Prof. Dr. Şebnem Yalınay Supervisor

Examining Committee Members

Assoc. Prof. Dr. Emel Aközer	(METU, ARCH)	_____
Asst. Prof. Dr. Şebnem Yalınay	(METU, ARCH)	_____
Asst. Prof. Dr. Berin F. Gür	(METU, ARCH)	_____
Prof. Dr. Can Baykan	(METU, ARCH)	_____
Assoc. Prof. Dr. Murat Soygeniş	(Yıldız Technical Uni.)	_____

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name: Halil Ayoğlu

Signature :

ABSTRACT

DIGITAL ARCHITECTURE AS THE EXTENSION OF PHYSICAL SPACES: ASYMPTOTE'S NEW YORK STOCK EXCHANGE VIRTUAL REALITY ENVIRONMENT

Ayoğlu, Halil
M. Arch., Department of Architecture
Supervisor: Asst. Prof. Dr. Şebnem Yalınay
Co-supervisor: Asst. Prof. Dr. Berin F. Gür

January 2005, 82 pages

The aim of this thesis is to develop an understanding of digital architecture as an extension to the physical spaces. The thesis claims that Virtual Reality Environments (VREs) coexist, supplement, support and extend the physical environments. VREs enable the users to deal with manipulable, multi-dimensional, interactive digital environment. Asymptote's New York Stock Exchange Three-Dimensional Trading Floor (NYSE 3DTF) VRE is a significant example to analyze digital architecture in this perspective. The 3DTF is a project where architecture and information bring each other into a new meaning through the spatialization of information in digital medium. The thesis analyzes how 3DTF VRE becomes extension to the existing actual NYSE in terms of four tools of analysis: visualization, navigation, interaction, and data integration. This thesis proposes to rethink architecture's relation with information through an understanding of extension.

Keywords: digital architecture, extension of real, virtual reality environments, information space

ÖZ

FİZİKSEL MEKANLARIN UZANTISI OLARAK DİJİTAL MİMARLIK: ASYMPTOTE'UN NEW YORK MENKUL KIYMETLER BORSASI SANAL GERÇEKLİK ÇEVRESİ

Ayoğlu, Halil
Yüksek Lisans, Mimarlık Bölümü
Tez Yöneticisi: Asst. Prof. Dr. Şebnem Yalınay
Ortak Tez Yöneticisi: Asst. Prof. Dr. Berin F. Gür

Ocak 2005, 82 Sayfa

Bu tez dijital mimarlığın fiziksel mekanların uzantısı olduğu anlayışını geliştirmeyi amaçlamaktadır. Bu tez Sanal Gerçeklik Çevrelerinin (SGÇ) fiziksel çevrelerle birlikte bulunduğunu, onları tamamladığını, desteklediğini ve onlara uzantı teşkil ettiğini savunur. Sanal ortam kullanıcıların manipüle edilebilir, çok boyutlu, interaktif dijital bir çevreye girmelerini ve içinde gezinebilmelerini sağlar. Asymptote'un New York Menkul Kıymetler Borsası Üç-Boyutlu Ticaret Katı (NYMKB 3BTK) SGÇ projesi bu görüşü ortaya koyan önemli bir örnektir. Bu proje, mimarlık ve bilginin birbirlerine digital ortamda yaratılan bilgi mimarisi üzerinden yeni anlamlar yükledikleri bir projedir. Bu tez, 3BTK SGÇ'nin gerçek New York Menkul Kıymetler Borsasına nasıl bir uzantı oluşturduğunu dört analiz gereci aracılığıyla: görselleşme, yönlendirme, etkileşim ve veri entegrasyonu ile inceler. Bu tez mimarlık ile bilgi arasındaki ilişkiyi bir uzantı anlamında düşünmeyi önerir.

Anahtar kelimeler: dijital mimarlık, gerçeğin uzantısı, sanal gerçeklik çevresi, bilgi mekanı

This work is dedicated to

My parents; Ayşe and Selahattin Ayoğlu… My gratitude can never be enough.

Fitnat and Benhür Kunter for their support, encouragement and tolerance in every moment of my life…

My newborn nephews Beliz and Berker for the meaning they brought into my life…

ACKNOWLEDGEMENTS

I give my deepest thanks and appreciation to:

My supervisor Asst. Prof. Dr. Şebnem Yalınay and co-supervisor Asst. Prof. Dr. Berin F. Gür for their interest, guidance, critical stand, encouragement and friendly attitudes towards me during the span of the thesis. It has always been a privilege to work with them.

Examining Committee Members; Assoc. Prof. Dr. Emel Aközer, Assoc. Prof. Dr. Murat Soygeniş, Prof. Dr. Can Baykan for their valuable critics and inspiring comments.

Reyhan and Şevki Ayoğlu, my uncle and aunt, for their directly or indirectly contribution to my profession.

Dr. Erol Lomlu, my master, and my guide in life, for his knowledge, wisdom, support, and making me believe in architecture and also in myself.

Çiğdem Aydın who believed in me more than I did,

Nur Evrim Barutcu, Özgür Türel, Mehmet Albayrak, Fatih Yılmaz, Hakan Tuncer and Nihat Türker for their encouragement and support,

Pınar Yılmaz, for her sweet care and love at most critical moments and for making me believe that the friendship and love last forever.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Problem Definition

This thesis aims at developing an understanding of digital architecture as an extension to physical spaces. In the real world, there exist limitations in terms of distance, gravity, scale, movement, which virtual medium does not have. In this sense virtual medium enables the users to deal with manipulable, multi-dimensional, interactive digital environment. The thesis argues that virtual environments coexist, supplement, support and extend the physical environments. Asymptote's New York Stock Exchange Three-Dimensional Trading Floor Virtual Reality Environment (NYSE 3DTF VRE) project is a significant example to illustrate this argument. It was conducted by Asymptote founded by Hani Rashid and Lise Anne Couture in New York, in 1989. The 3DTF is not a digital replica of the existing NYSE. It is a project where architecture and information bring each other into a new meaning. The thesis will focus on how NYSE 3DTF VRE becomes extension to the existing actual NYSE in terms of the spatialization of information. In this project, "reading, correlating and navigating through massive amounts of information"[1] is eased and architecture's relation with information is recast anew based on the need for spatialization of information. (See Appendix A for conceptual relations of the framework)

Digital space and digital architecture are not to replace or substitute the physical space or the facilities in physical space. Rather, according to this thesis, the former expands, augments and enlarges the latter. Despite the broad scope of digital architecture, the thesis approaches to the digital architecture as a complementary to the existing physical spaces; it is accepted as an extension to the physical space.

[1] Hani Rashid and Lise Anne Couture, 2002, *Asymptote: Flux* (London: Phaidon,) p. 34

In the thesis the architecture of and for the digital medium will be named as digital architecture. The focus will be on the relation between computer-generated environments designed in and for the digital medium and the physical spaces. To begin with, I will elaborate the meanings of extension and digital architecture as an extension to physical spaces.

1.2 Digital Architecture as an Extension to Physical Space(s)

Digital technologies enable architects to get into a non-gravity realm where animation, simulation, modeling, and fast drawing techniques are available. These capabilities define new areas of interest and research for architects, while bringing forth the concept of digital architecture.

How does digital medium constitute an extension to the real? When referred to the dictionary definitions of the word 'extension' followings are stated: "the spreading of something into new regions… an addition that extends… expanding in scope… making more widely available… enlargement… spreading… augmentation."[2]

As William Mitchell discussed in his book *City of Bits*, in earlier times, telegraph and telephone were extensions, which have helped human beings to relay their written messages and voice surpassing distances.[3] In Mitchell's examples of telegraph and telephone it is the distance restriction, which is being overcome through some kind of virtuality since it was not the voice or the message itself getting to the destination but their representations. Through telephone the voice is being extended through distances. Telephone helps extend one's voice via its technological interface. Similarly, with the introduction of the digital technologies not only distance but additional real world restrictions, like gravity, scale, time, space and movement can not be considered as limitations in digital environments. One can extend physical spaces into virtual medium eliminating the restrictions of them. With this respect,

---

[2] *Encarta® World English Dictionary ©,* 1999, Microsoft Corporation, All rights reserved, Developed for Microsoft by Bloomsbury Publishing Plc. [CD-Rom]

[3] William J. Mitchell, 1995, *City of Bits: Space, Place, and the Infobahn.* (Cambridge, Mass.: MIT Press,) p. 36.

virtual representations or interpretations of the physical spaces become free of constraint. They become immaterial extensions of their bodily counterparts. Virtual possibilities also enable our bodies to extend into digital medium.

In digital space one can extend beyond the traditional forms and materials existing in the physical world. There are no doors or windows. There are links for changing addresses or locations. Constraints in regards to scale are not as sharp as they are in the physical spaces. A virtual environment or a building can be modeled in any scale. There is no restriction concerning gravity. One can fly through or animate a model in the space surpassing gravity constraint, which exists in physical space. Time is also no more a constraint. One can access to a virtual library or a museum anytime without waiting opening hours to come. The virtual library or museum would never close. Access to a book or a painting for view takes few seconds. Furthermore, spatial compression is also possible in such places. There is not any requirement for the allocation of huge spaces or hallways for display or access purposes. One can reach the items or video displays just by clicking an icon or a link. For instance, in the field of finance, with the introduction of electronic trade, which aims to supplement the physical market, the stock market is extended allowing huge number of investors from different locations to utilize transaction system via virtuality. It serves as an extension to the physical markets allowing easy and fast access to buying and selling stocks at anytime. Mitchell states:

> In 1992 Reuters, the Chicago Mercantile Exchange, and the Chicago Board of Trade opened Globex, a very ambitious twenty-four-hour electronic trading system for futures and options contracts. It took about as long to design and builds (four years), and cost about as much ($70 million) as a major new trading building. But it has no floor; buy and sell orders are entered electronically into the system, prices are set by a process of computer matching with incoming orders, participants in the trade are properly notified, verification is sent to the Chicago exchange clearing center, and buyers' and sellers' accounts are adjusted-all in a few seconds. Its chairman claims, *this is a way to extend our market around the globe across all borders and time zones*.[4]

Similarly going to a theater show would require one to buy a ticket timely and spend some time in traffic to reach the show. Whereas when shows in digital medium are concerned, one can enter a show via few clicks.

[4] Ibid., p. 85. [emphasis mine]

Another example to the idea of extension is digital media in print, press and broadcasting sector. The aim is not to substitute, but to supplement the existing conditions. For instance, print media cannot include real time updates on a regular basis; whereas digital medium enables hourly or more frequent updates.

Amanda Griscon refers to the evolution of a new medium through interpretation of Marshal McLuhan's major works *Understanding Media: the Extensions of Man and the Medium is the Message* as follows:

> A new medium is never an addition to an old one, nor does it leave the old one in peace. It never ceases to oppress the older media… Each medium… reveals and communicates a unique aspect of reality, of truth. Each offers a different perspective, a way of seeing an otherwise *hidden dimension of reality*. It's not a question of one reality being true, the other ones distortions... taken together they give us a more complete whole...[5]

In his essay *Image of Architecture in Electronic Age,* Toyo Ito also refers to McLuhan and makes a relation with architecture:

> In 1960s, M. McLuhan said that our clothing and shelter are the extended form of our skin. From old times, architecture has served as a means to adjust ourselves to the natural environment. The contemporary architecture needs to function, in addition, as a means to adjust ourselves to the *information environment*. It must function as the extended form of skin in relation both to nature and information at once. Architecture today must be a media suite. People, when clad in a mechanical suit called automobile, had their physical body expanded. People clad in a media suite have their brain expanded. Architecture as media suit is the externalized brain.[6]

As expressed by McLuhan and clarified by Ito, in information laden electronic age, contemporary architecture develops a new role and acts as a medium for expanding the physical body and brain into information environment. With this respect, this thesis dwells on how physical body and brain is expanded for obtaining information through digital architecture.

---

[5] Amanda Griscon, Aug. 2003, "Trends of Anarchy and Hierarchy: Comparing the Cultural Repercussions of Print and Digital Media," *Cyberspace and Critical Theory*, [Internet, WWW,] ADDRESS: http://www.cyberartsweb.org/cpace/infotech/asg/ag8.html [Accessed: 20 Aug 2004] [emphasis mine] p.1

[6] Marshall McLuhan, 1987, *Understanding media :the extensions of man*, (London: Ark) quoted in Toyo Ito, Mar 2000, "Image of Architecture in Electronic Age," [Internet, WWW,] ADDRESS: http://www.um.u-tokyo.ac.jp/dm2k-umdb/publish_db/books /va/english/ virtual/ 01.html [Accessed: 20 Aug 2004] [emphasis mine] p.1

Figure 1.1 Representation of the Concept "Extension" (Source: Joel Kotkin and Ross C. DeVol, 2001, *Knowledge-Value Cities In The Digital Age* (Milken Institute,) [Internet, WWW, PDF,] ADDRESS: http://www.pittsburghregion.org/public/cfm/library/reports/Knowledge-ValueCitiesintheDigitalAge.pdf [Accessed: 30 Dec 2004] cover page, [edited by Halil Ayoğlu, 2004])

As stated earlier, digital space offers conditions that surpass the constraints of physical space like distance, gravity, scale, movement, time and space. When architectural design in the virtual environment is concerned, the condition of "metamorphosis" is an illustrating example. "Metamorphosis" turns out to be a design concept by which the possibilities of digital medium are explained. It means "change in form, through time or space" [7] as referred by Marcos Novak. Metamorphosis is not possible to be visualized in the physical world with the same ease due to the physical space constraints like scale, movement, etc. With the developments in digital technologies, all these limitations are overcome in digital space. In particular, through digital architecture, information environments in this space, serve as extensions of the physical ones. The followings are considered:

[7]Marcos Novak, "Liquid Architectures in Cyberspace," in Michael Benedikt, ed., 1991, *Cyberspace: First Steps*, (Cambridge: The MIT Press,) p.250.

1 Physical spaces extend into digital medium by the creation of digital environments.

2 Information pertaining to physical world extends into digital medium via the spatial presentation of the same information in that environment.

3 Users extend into digital medium through digital architecture, by means of which the environment is designed so as to make the user feel like he/she is present in that environment.

In order to understand how digital architecture becomes extension to the physical space; it is required to realize the transformation of architecture in terms of context and process of design in digital environments.

In his book *Hybrid Space,* Peter Zellner points out the impacts of developing information technologies on architecture as follows:

> The cultural and social revolution brought on by telecommunications and information technologies is rapidly transforming the field of *architecture*… against this shifting background, architecture itself is mutating, redefining its boundaries, its essential codings, to adjust to an increasingly supple and volatile world. *Architecture is recasting itself...*[8]

Leo Gullbring referring to Marcos Novak states that:

> …compared to ordinary architecture, this new tectonics presents a loss of distance, a new, technologically augmented spatial continuum, a multi-dimensional spectrum spanning manifold ranges: from physical to virtual, from visible to invisible, from static to liquid, from handmade to generative…"[9]

Thus, the possibilities created by digital world are transforming architecture. Digital technologies in architecture support both the drawing and design medium. For drafting and presentation purposes, this medium offers advanced possibilities for high speed drafting, computation, modulation, modeling and animation. The processes of design on the other hand require a further mentality in the digital medium. The computer

[8] Peter Zellner, 1999, *Hybrid Space*, (London: Thames & Hudson,) p. 8 [emphasis mine]

[9] Av Leo Gullbring, 2001, "Marcos Novak," [Internet, WWW,] ADDRESS: http://home.swipnet.se/~w-35482/novak2.htm [Accessed: 20 Aug 2004] p.1

logic being based on “algorithmic and relational thinking” also serve as a major force for shaping the design processes in this environment. According to the Encarta World English Dictionary, algorithmic and relational thinking automatically involve a logical sequence of steps for design problem solving, often involving repetition of the same basic operation which could be written out as a flow chart. “Algorithmic and relational thinking” in digital medium bring new meanings to architecture. Algorithmic and relational thinking gives an opportunity to approach problem-solving process in a multi-dimensional way by presenting various solutions at the same time. Algorithmic and relational thinking is the base and the core point of the software. For instance, the understanding of proportion is not only visual pleasure of the user but also it has a functional role of the environment which helps to perceive and orient the user in a logical and systematic way. The proportions help user to identify and understand the relations between objects and information. Thus in this sense, the user can perceive an information from the proportional environment.

To conclude, algorithmic and relational thinking provide an essential opportunity to use computational and generative features of computers.

1.3 The Case: NYSE 3DTF VRE

There are many and diverse examples of information environments in digital medium like virtual campuses, libraries and so on. Whereas, the most significant is Asymptote’s NYSE-3DTF VRE project for following reasons:

1. The project is the first business application of an interactive virtual architecture. In this sense it is a pioneer when these kinds of applications are considered.

2. Its actual correspondent in the physical space is already a very important financial center which constitutes the heart of trade and finance.

3. Information environment has been designed specifically by architects unlike what has been in the past for most of the web applications

which were being designed by computer engineers and web designers.

4 There is an incredibly fast change of information, which changes the environment in synchronization.

5 It is a large-scale information environment.

6 It is one of the unique architectural examples to understand and discuss how the architecture of/for information is created in digital media.

7 It concentrates on both virtual and real architecture as parallel tracks.

The actual New York Stock Exchange had problems to manage storing the ever-increasing information with the physical setting and Asymptote is asked to solve this problem. Asymptote's proposal was to design the virtual space rather than the physical one in order to overcome the difficulty of gathering and controlling the daily real time information. Thus, the concept of 3DTF has emerged.

3DTF is not an exact representation or a substitute for the actual NYSE. Rather it is a digital version. It is an architecturally designed information environment designed. In this digital project, Asymptote facilitate "reading, correlation and navigation of massive amounts of information"[10] in a spatial, interactive, manipulable and dynamic way. This project, equipped with the advantages of cyberspace, provides the clients of the Stock Exchange very comprehensible and easy access to vast amounts of information. In 3DTF the users are enabled to store, review, process, correlate, animate, and modulate massive amounts of information. The crucial aspect of the 3DTF project is its being a spatialized interactive information environment.

[10] Hani Rashid and Lise Anne Couture, 2002, *Asymptote: Flux* (London: Phaidon,) p.35

1.4 Method of Analysis

The method of analysis is developed in reference to the studies of Mary Lou Maher and Julio Bermudez together with Jim Agutter and Dwayne Westenskow. Their studies are respectively *The Analysis of 3d Virtual Architecture*[11] and *Data Representation Architecture: Visualization Design Methods, Theory and Technology Applied to Anesthesiology.*[12]

In light of above-mentioned studies by Maher and Bermudez et.al, the thesis makes an analysis of NYSE 3DTF VRE project. In doing so, the study aims to understand how information is spatialized, how architecture of and for information is created in Asymptote's project. Thus, four major aspects of the framework offered by the thesis for this particular project are:

1. Visualization
2. Navigation
3. Interaction
4. Data integration

These aspects have been chosen as tools of analysis to understand how the spatialization of information is realized in digital environments.

Cyberspace offers a convenient medium for the spatial formation of information. For the thesis, spatialization of information means "the representation of data as a collection of objects in space… in order to make data easier to comprehend and manipulate."[13]

---

[11] Mary Lou Maher and Ning Gu, 2004, "Virtual Architecture," [Internet, WWW,PPP].ADDRESS: www.arch.usyd.edu.au/~mary/DESC9103/va_intro.ppt [Accessed: 17 Dec 2004] p.29

[12] Julio Bermudez, Jim Agutter and Dwayne Westenskow, 2000, "Data Representation Architecture: Visualization Design Methods, Theory and Technology Applied to Anesthesiology." *ACADIA 2000.* [Internet, WWW,] ADDRESS: http://www.arch.utah.edu/people/faculty/julio/acadia2000.pdf [Accessed: 20 Aug 2004] p.1

[13]M*icrosoft Press® Computer and Internet Dictionary ©,* 1997, 1998, 1999, Microsoft Corporation, All rights reserved. [CD-Rom]

A quick view on the meanings of the above mentioned tools of analysis will be helpful here for clarification. To begin with, the meaning of word "visualization" according to *Encarta Dictionary* is "the creation of a clear picture of something in the mind… forming a visual image of something."[14] In this context, the word "something" refers to information. The thesis refers to "visualization" as the usage of visual aspects like form, layout or usage of metaphors for clarity and ease of comprehension. By this way, ever increasing amount of information can be presented to facilitate perception and interpretation. This presentation is an important concept in designing information space for a convenient visualization by the utilization of spatial metaphors.

The second aspect of the framework is navigating in digital environment. For the *Encarta Dictionary* "Navigation" means "the act or task of moving through a place or along a route"[15]

"Interaction," which is the third aspect of the framework, refers to the user and the computer mutually having an effect on each other.

"Data integration" means organization of data in such a consistent and coordinating way constituting a balanced whole. Data integration in VR environment refers to how the information and the changes in the information are integrated into the digital space.

When all above mentioned criteria are integrated to each other, the environment will have n-dimensional property which includes flexible, spatial, interactive, dynamic, fluid, metamorphic, navigable, and immaterial information environment. Information is the major force changing the environment. Digital architecture is not only architecture for information, but it is also reshaped and redefined by information.

---

[14] *Encarta® World English Dictionary* ©, 1999, Microsoft Corporation, All rights reserved, Developed for Microsoft by Bloomsbury Publishing Plc. [CD-Rom]

[15] Ibid.

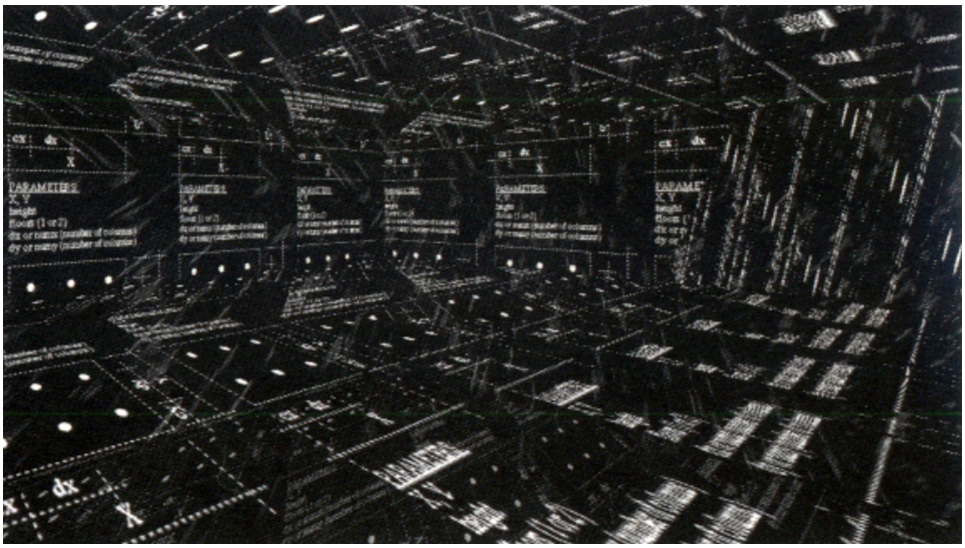

Figure 1.2 Multi Dimensionality in Architectural Data Space: xyz, time, information, Florian Wenz, 1993. (Source: Gerhard Schmitt, 1999, *Information Architecture: Basis and Future of CADD,* Trans., Lucinda Byatt, (Basel; Boston; Berlin: Birkhauser,) p.11

To conclude, in regards to this approach Bermudez states that "digital environments will not replace the built environment as a major architectural market, but they will significantly complement it…"[16] They are not to replace physical environments or physical architecture but to co-exist with each other. In the same sense, Paul Virilio states that, "the space in the future would be both of real and of virtual nature."[17] For him, architecture will take place in both domains, the virtual and the real. Digital architecture is not meant to be a substitute for physical architecture; rather it serves to open up new horizons for architecture both in physical and virtual reality.

[16] J. Bermudez and K. King, 1995, "Architecture in Digital Space: Actual & Potential Markets," Kalisperis & Kolarevic (eds.), *ACADIA 1995* (Seattle, WA: University of Washington), pp. 405-423 [Internet, WWW]. ADDRESS: http://www.arch.utah.edu/people/faculty/ julio/cyber2. htm, [Accessed: 20 Aug 2004] [emphasis mine]

[17] Andreas Ruby, October 1993, "Architecture in the Age of Its Disappearance - An Interview with Paul Virilio", John Beckmann, ed., 1998, *The Virtual Dimension* (New York: Princeton Architectural Press,) p.182.

CHAPTER 2

DIGITAL ARCHITECTURE

Cyberspace and virtual reality are the essential concepts to develop an understanding of digital architecture. Cyberspace is the environment in which digital architecture can be realized. Whereas, virtual reality is the major condition for the realization of concerned information environment. Thus, before discussing digital architecture, a brief survey on these concepts is required.

2.1 Discussions on Cyberspace

Cyberspace is a multi-dimensional and a bit-based space that can be "entered" in any geographical location. It is free from the bounds of physical space and time. It would be a mistake to associate it only with the internet. Since this association would fail to cover the full area of cyberspace, and underestimate the capabilities offered by it. It is important in the sense that cyberspace offers further spatial and multi dimensional qualities for architectural thinking and design.

The term, Cyberspace is introduced by William Gibson in his science-fiction book *Neuromancer.* His definition of cyberspace is characterized in an oft-quoted passage as:

> A consensual hallucination experienced daily by billions of legitimate operators… A *graphic representation of data* abstracted from the bank of every computer in the human system. Unthinkable complexity. Lines of light ranged in the non-space of the mind, clusters and constellations of *data*…[18]

[18] William Gibson, 1984, *Neuromancer*, (London: Harper Collins), p. 51, quoted in Mike Featherstone and Roger Burrows. eds. 1995, *Cyberspace/Cyberbodies/Cyberpunk: Cultures of Technological Embodiment* (London: SAGE), p. 6. [emphasis mine]

Mike Featherstone and Roger Burrows explain Gibson's approach in their book *Cyberspace/Cyberbodies/ Cyberpunk: Cultures of Technological Embodiment* as follows:

> In this fictional world, cyberspace is a *global computer network of information* which Gibson calls 'the matrix', which operators can access through headsets via a computer terminal. Once in the matrix, operators can 'fly' to any part of the *vast three-dimensional system of data coded into various colorful iconic architectural forms* laid out beneath them like a vast metropolis: a city of data… Once a particular location has been selected, it is possible to zoom in so that one moves inside the *three-dimensional representation of the data* in order to scan particular areas. Gibsonian cyberspace also allows for highly 'realistic' interactions between iconic representations of operators so that co-presence can be simulated within a myriad of different highly vivid environments.[19]

Whereas, according to Michael Benedikt; through cyberspace, "a whole new space is opened up by the very complexity of life on earth."[20] Benedikt states "cyberspace is a globally networked, computer-sustained, computer-accessed, and computer-generated, multi-dimensional, artificial or 'virtual' reality."[21] Benedikt focuses on the significance of computer medium for architecture. As can be understood on the basis of above definitions, cyberspace offers an alternative medium for architecture.

Michael Heim, on the other hand, considers cyberspace as an electronic extension of reality whether it exists in real or not. Heim, in his book *The Metaphysics of Virtual Reality,* states that "[we] can travel endlessly in cyberspace, without limits, for cyber-space is electronic, and electronically we can represent not only the actual physical universe but also possible and imagined worlds... a nonphysical secondary realm."[22]

---

[19] Mike Featherstone and Roger Burrows, "Introduction", in Mike Featherstone and Roger Burrows. eds. 1995, *Cyberspace/Cyberbodies/Cyberpunk: Cultures of Technological Embodiment* (London: SAGE), p. 6. [emphasis mine]

[20] Michael Benedikt, 1991, "Introduction", Michael Benedikt, ed., *Cyberspace: First Steps* (Cambridge: The MIT Press), p.124.

[21] Ibid., p.122.

[22] Michael Heim, 1993, *The Metaphysics of Virtual Reality,* (New York: Oxford University Press), p. 80

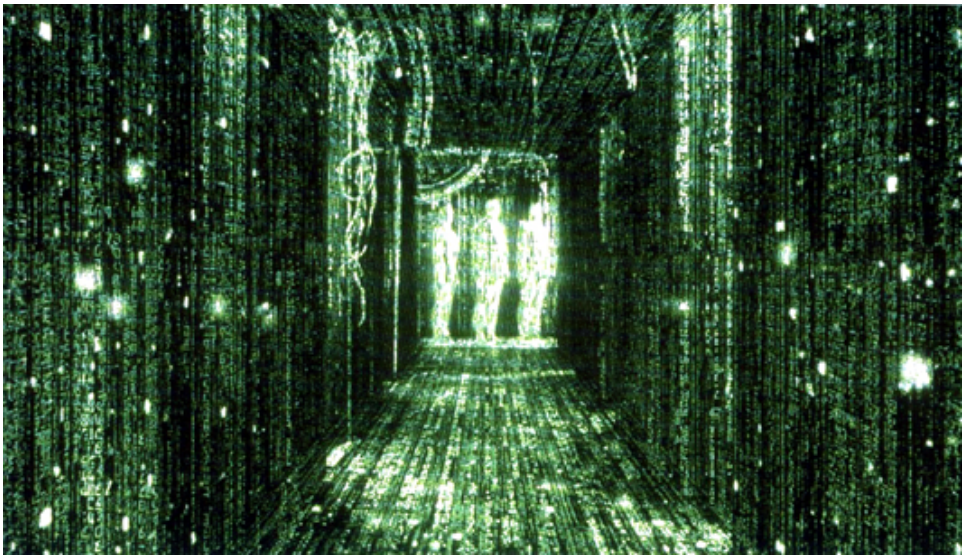

Figure 2.1 The key representation of cyberspace/ The Matrix (source: Martin Dodge and Rob Kitchen, 2001, *Atlas of Cyberspace,* (NY; London: Addison-Wesley) p.236)

Cyberspace offers a multi dimensional environment. It is spatially limitless, navigable and interactive. This is due to the fact that there are not any physical constraints in cyberspace.

According to Marcos Novak cyberspace is a "modulated space, an architectural space…To the extent that this development [i.e., the creation of cyberspace] inverts the present relationship of human to information, placing human within the information space, it is an architectural problem…"[23] He classifies the relation between architecture and cyberspace into three topics as follows: "cyberspace is architecture; cyberspace has an architecture; and cyberspace contains architecture."[24] But for him "more than asserting that there is architecture within cyberspace, it is more appropriate to say that cyberspace cannot exist without architecture…"[25]

[23] Marcos Novak, 1991, "Liquid Architectures in Cyberspace", in Michael Benedikt, ed., *Cyberspace: First Steps* (Cambridge: The MIT Press), p.226.

[24] Ibid.

[25] Ibid., p.243.

Bermudez in *Architectural Visions: Non-Verbal Essays on Cyberspace* points out the relation between cyberspace and architecture as follows:

> The situation is surprising given that (1) architects are experts in the use of representations and the design of 3D objects and immersive environments; and (2) cyberspace is (a) a representational matrix supporting depictions of any real or imaginary construct; and (b) a place of immersive experiences (thus perceivable, usable, and designable as a true environment). [26]

As is also stated by Bermudez that cyberspace is significant when the design of VRE is in consideration.

Additional possibilities offered by cyberspace are as follows according to Bermudez: "…dynamic order, movement, transformation, and time, things that only the arrival of cyberspace has made possible to describe, visualize, simulate, and design…" [27] He goes on to state that, "…Considering that no other medium or technique of architectural representation and design may have ever offered so many architectural opportunities as cyberspace, this situation is at the very least amusing."[28]

Through these possibilities architecture goes under a transformation. According to Novak it is the "transition from real space to cyberspace… from static to dynamic, from passive to active, from fixed in all its forms to the fluid in its ever-changing countenance…"[29] According to Benedikt:

> *The dimensions, axes, and coordinates of cyberspace* are thus not necessarily the familiar ones of our natural, gravitational environment: though mirroring our expectations of natural spaces and places, they *have dimensions impressed with informational value appropriate for optimal orientation and navigation in the data accessed.* In cyberspace, information-intensive institutions and businesses have a form, identity, and working reality -…quite literally an architecture- that

---

[26] Julio Bermudez, "Architectural Visions: Non-Verbal Essays on Cyberspace," Work presented at the 4th CyberConf, The Banff Centre for the Arts, Banff, Canada, 1994, *Collected Abstracts of the Fourth International Conference on Cyberspace.* (The Banff Centre for the Arts, Banff, Canada,) p. 19[Internet, WWW,] ADDRESS: http://www.arch.utah.edu/people/faculty/julio/visions.htm [Accessed: 20 Aug 2004] p.10

[27] Ibid.

[28] Ibid.

[29] Marcos Novak, 1991, "Liquid Architectures in Cyberspace", in Michael Benedikt, ed., *Cyberspace: First Steps* (Cambridge: The MIT Press), pp.242-243

> is counterpart and different to the form, identity, and working reality they have in the physical world.[30]

In parallel, Sherry Turkle, in her book *Life on the Screen* states that today people are "embracing the notion that computers may extend an individual's physical space."[31]

Thus, cyberspace is a digital space where the computer generated electronic medium serves as a new environment for architectural work. Cyberspace both offers the conditions and requires digital architecture. Whereas, the major aspect of the cyberspace is its virtuality. Thus VR and VRE are to be defined for a better understanding of digital architecture.

2.2 Virtual Reality Environments (VRE)

Virtual reality (VR) is a computer-generated experience of being in another environment than one actually is in. It is either a representation/interpretation of an actual environment or presentation of a totally imaginary one.

In his essay *The Design of Virtual Reality* Heim very briefly summarizes the short history of the term "virtual reality" as follows:

> Jaron Lanier coined the phrase in 1986… Researchers at MIT shunned the phrase in the early 1990s. Instead of 'virtual reality', they spoke of 'virtual environments'. The word 'reality' in 'VR' glowed with an aura similar to 'artificial intelligence'… Military scientists preferred 'synthetic environments'. Researchers at the Human Interface Technology Lab at the University of Washington in Seattle urged 'virtual worlds'. Against all protests, however, Lanier's phrase held its own.[32]

He goes on to state, in the *Metaphysics of Virtual Reality*:

> Virtual reality pertains to convincing the participant that he or she is actually in another place, by substituting the normal sensory input received by the

---

[30] Michael Benedikt, "Cyberspace: Some Proposals," in Michael Benedikt, ed., 1991 *Cyberspace: First Steps* (Cambridge: The MIT Press), p. 123 [emphasis mine]

[31] Sherry Turkle, 1995, *Life on the Screen,* (NY: Simon & Schuster,) p. 2.

[32] Michael Heim, "The Design of Virtual Reality," in Mike Featherstone and Roger Burrows, ed., 1995, *Cyberspace/Cyberbodies/Cyberpunk: Cultures of Technological Embodiment* (London: SAGE), p. 65.

> participant with information produced by the computer. This is usually done through three-dimensional graphics and input-output devices that closely resemble the participant's normal interface with the physical world.[33]

Peter Weishar defined the boundaries of VR in his book *Digital Space*, stating:

> Any of various forms of computer-generated 3D environments, the more interactive and immersive the better. Virtual reality can be used to describe simple walkthroughs on desktop computers to complex systems using stereoscopic images in head-mounted displays (HMD), and sensor gloves for manipulation of objects in virtual environments.[34]

As it is mentioned above, the virtual environment can be lived and perceived mainly in two ways:

1. with screen-based interfaces
2. with complex systems interfaces like stereoscopic images in head mounted displays, etc.

The thesis mainly focuses on screen based relation since the Asymptote's NYSE 3DTF project in which the interaction between the perceiving subject and the object of perception (i.e. 3D financial information) is realized on the computer screen.

---

[33] Michael Heim, 1993, *The Metaphysics of Virtual Reality,* (New York: Oxford University Press) p.160.

[34] Peter Weishar, 1998, *Digital Space: Designing Virtual Environments* (New York: McGraw-Hill,) p.241

Figure 2.2 (left) Complex Systems Interface, Head- Mounted Display worn by Donald Vickers (source: Packer, Randall and Ken Jordan, 2002, *Multimedia; From Wagner to Virtual Reality*,W.W, (Norton, New York) [Internet, WWW,] ADDRESS: http://www.artmuseum.net/w2vr/timeline/Sutherland.html# [Accessed: 30 Dec 2004]

Figure 2.3 (right) Screen-Based Interfaces (Photograph by Halil Ayoğlu, 2004)

Featherstone and Burrows defined VR as a "system which provides a realistic sense of being immersed in an environment… a computer-generated visual, audible and tactile multi-media experience… a medium which simulates a sense of presence through the use of technology…"[35] Understanding its concepts is essential to understand VR according to Heim. He indicates these concepts as follows:

> *artificial reality*, as when the user's full-body actions combine with computer-generated images to forge a single presence; *interactivity*, as when the user enters a building by means of a mouse traveling on a screen; *immersion*, as when the user dons a head-mounted display enabling a view of a three-dimensional animated world; networked environments, in which several people can enter a virtual world at the same time; *telepresence*, in which the user feels present in a virtual world while robotic machines effect the user's agency at a remote location in the actual primary world.[36]

[35] Mike Featherstone and Roger Burrows, "Introduction", in Mike Featherstone and Roger Burrows. eds. 1995, *Cyberspace/Cyberbodies/Cyberpunk: Cultures of Technological Embodiment* (London: SAGE), pp.5-6

[36] Michael Heim, 1993, *The Metaphysics of Virtual Reality,* (New York: Oxford University Press), p. 160-161.

Three-dimensionality, interaction (manipulation of objects), and immersion (the feeling of being inside the computer-generated environment) are critical to understanding the concept of VR and eventually digital architecture.

In the essay *Virtual Worlds: No Interface to Design*, Meredith Bricken states that VR has a new paradigm for creating virtual environments, different than the paradigms for "screen-based interface design."[37] The difference between interface and inclusion should be elaborated. The former is viewing 3D graphics on a screen as in the case of NYSE 3DTF VRE project, and the latter allows one to interact directly with various information sources by the help of devices like head-mounted display and sound systems for Bricken.[38] In his essay *Cyberspace - the World in the Wires,* Rob Kitchin indicates the importance of interaction and inclusion by stating that "[i]nstead of the users being spectators of a static screen, they are participants in an environment that responds…it has three essential components: it is inclusive; it is interactive; and the interaction is in real time."[39] In VR the user is not only a passive viewer, but also a player modifying the parameters of the environment in real-time interaction. Referring to this interaction, taking place via VR; Daniela Bertol states in her book *Designing Digital Space*:

> *This interaction is the generator of the representations of the virtual world.* Mathematical models, planets and stars, human body organs, virtual cities resurrected from archeological sites, and financial data become three-dimensional worlds that can be accessed, inhabited, walked through, and manipulated. While the content of the virtual world could also be provided in different computer simulations and visualizations—animations, graphics charts, and rendered images—*only in virtual reality applications can interaction between the perceiving subject and the object of perception be possible*, often following natural actions such as moving the head and hands or walking. It is because of this "natural" interaction between the computer-generated world and the user that *VR is defined as the ultimate interface between man and machine. Architectural design in a VR environment provides for the expression of ideas and the exploration of alternatives in a way, which is both comprehensive and revolutionary.*[40]

---

[37] Meredith Bricken, "Virtual Worlds: No Interface to Design", in Michael Benedikt, ed., 1991, *Cyberspace: First Steps* (Cambridge: The MIT Press), pp. 364-365

[38] Ibid., pp.364-368

[39] Rob Kitchin, 1998, *Cyberspace-The World in the Wires* (Chichester: John Wiley&Sons) p.11

[40] Daniela Bertol, 1996, *Designing Digital Space: An Architect's Guide to Virtual Reality.* (New York: J. Wiley & Sons, Inc.), p. xv [emphasis mine]

VR, as a convenient interface between the man and the computer, enables interaction and immersion, and, in that sense, it becomes a design environment for digital architecture. In his book *Information Architecture*, Gerhard Schmitt explains VR and digital architecture as follows:

> Architecture as a discipline between science and art has developed the ability to communicate powerful ideas with extremely abstract means of presentation. Since the beginnings of Modern Architecture, these abstractions have begun to influence design itself and the creation of new form. Design abstractions become the basis for future architecture, while the previously built architectural reality turns into an abstraction of the past. Thus, with the dissolving boundary between reality and abstraction and the tendency of architecture to move away from the craft of building towards the art of creating virtual structures, VR becomes the perfect vehicle to simulate new architecture. This could eventually result in the dematerialization of architecture.[41]

2.3 Contemporary Discussions on Digital Architecture

In digital architecture, the computer is at the same time instrument, infrastructure and design environment. Its medium is cyberspace, material is information and it is realized by establishing virtual reality environments. In contemporary debates, there are several approaches to define what we call digital architecture.

In his essay *Solid and Virtual Architecture*, Sebastian Baehring mentions the relation between physical architecture and digital architecture as follows:

> Within "solid [physical] architecture" digital media is defined as the characteristic tool for the development of architecture to be built within the real physical world. The term "virtual [digital] architecture" defines digital media as the constituent space for architecture. The space occupied by virtual architecture is called "digital space". Virtual architecture does not exist in physical space.[42]

---

[41] Gerhard Schmitt, 1999, *Information Architecture: Basis and Future of CADD,* Trans., Lucinda Byatt, (Basel; Boston; Berlin: Birkhauser,) p.27.

[42] Sebastian Baehring, 2000, "Design Studio: Introduction to the Design Studio [digital_space]: Solid and Virtual Architecture," Bauhaus - University of Weimar. [Internet, WWW]. ADDRESS: http://infar.architektur.uni-weimar.de/infar/engl/teachings/archive/design_studios/digital_space/ss01/lectures/000/print.html [Accessed: 20 Aug 2004].

Daniela Bertol defines the context of digital architecture as follows:

> Digital architecture does not exist in physical material, such as stone, glass, bricks, concrete, and so on, but is made of databases—sets of numbers stored in electromagnetic format. These databases will create representations as visual simulations of architecture made of the same physical materials… But digital architecture is not only a series of representations of an ideated physical place; it also serves as a metaphor in the creation of places in cyberspace. Here the use of architecture is meant for the creation of places for human interaction, which does not necessarily resemble traditional physical architectural places. Places in the internet universe such as MUDS, MOOS, Chats and Websites can be portrayed as examples of digital architecture.[43]

In his book *Envisioning Cyberspace* Peter Anders explains that MUD refers to the "Multi-user Domain… and it is a place for role-playing games Dungeons and Dragons… MOO refers to MUD Object-Oriented."[44] Objects and verbs can be created on a MOO. MOOs allow participants to manipulate their bodies and objects around them. Pavel Curtis, the inventor of MOO software, states the following:

> A MUD [Multi-User Dungeon or, sometimes, Multi-User Dimension)] is a network-accessible, multi-participant, user-extensible virtual reality whose user interface is entirely textual. Participants [usually called players] have the appearance of being situated in an artificially-constructed place that also contains those other players who are connected at the same time.[45]

Bermudez's criticism of seeing digital space only as a virtual environment, and Asymptote's approach to the differentiation of virtual architecture and virtual building help to reveal the definition of digital architecture in a more clear way.

To Bermudez; "digital space is predominantly seen as only a virtual studio for real world designs,"[46] which is referred by him as a "lack of *vision which* may result in a

---

[43] Bertol, Daniela, 1996, *Designing Digital Space: An Architect's Guide to Virtual Reality*, (New York: J. Wiley), p. 57

[44] Peter Anders,1999, *Envisioning Cyberspace*, (NY: McGraw-Hill), pp.137-138

[45] Pavel Curtis, 1992, *Mudding: Social Phenomena in Text-Based Virtual Realities.*Submission to the 1992 Conference on Directions and Implications of Advanced Computing, [Internet, WWW]. ADDRESS: ftp://parcftp.xerox.com/pub/MOO/papers/DIAC92.txt [Accessed: 17 Dec 2004]

[46] J. Bermudez and K. King, 1995, "Architecture in Digital Space: Actual & Potential Markets," Kalisperis & Kolarevic (eds.), *ACADIA 1995* (Seattle, WA: University of Washington), pp. 405-423 [Internet, WWW]. ADDRESS: http://www.arch.utah.edu/people/faculty/ julio/cyber2. htm, [Accessed: 20 Aug 2004] [emphasis mine]

loss of the potential architectural services that digital worlds will require."[47] Utilizing digital space only as a virtual tool for real world designs excludes the potentials or alternative experiences that the digital space may offer as a virtual environment/space. Bermudez's visions of digital space help to construct the definition of digital architecture:

> Digital space, a reality of representations, is an *environment* with nature, functions, aesthetics, order, etc., not necessarily following or referring to classical reality. In this world, may people find and generate information, work, meet other people and seek entertainment. According to this vision, architecture should play a major role in the conceptualization, organization, and design of such an *alternative reality*. In other words, digital space is a virtual place in its own right that has no other justification than offering alternative experiences, structures and events to those of classical reality. Architecture designed for this interpretation of digital space is meant to be constructed in digital space and is not to be a part of the physical world, except to be experienced by people. We will call this architecture *digital.*[48]

On the basis of the definition of digital architecture by Bermudez, the thesis claims that digital space, being approached not as a tool but as a virtual environment/space, could become an extension to the physical space. Asymptote's differentiation of virtual architecture and virtual buildings, which is also quite close to Bermudez's approach is helpful to explain the thesis' argument.

Asymptote's definition of virtual architecture is equivalent to the digital architecture proposed by this thesis. According to Hani Rashid:

> *Virtual architecture* is perhaps best understood as spatiality based on the alteration of reality, on mapping flux, and on the transformable possibilities of geometry within such realms. …It is important to draw a distinction here between *virtual architecture* and virtual buildings, just as one draws a distinction between architecture and buildings. In *virtual architecture* the assumption is that spatial, informational, and temporal circumstances provoke experiences and create assemblies that are tangible and plastic. Virtual buildings, on the other hand, tend to be representations of buildings and built space as we already know them to be: for example, a virtual rendition of Le Corbusier's unbuilt Palace of the Soviets complex. This is actually virtual representation, which we tend to call virtual buildings; especially we can inhabit them in three-dimensional representations. *Virtual architecture* does not represent or attempt to mimic any aspect of "real" building; rather, it is

[47] Ibid.

[48] Ibid. [emphasis mine]

> architecturally significant for entirely different reasons. [49]

Another important approach to define digital architecture is put forward by Marcos Novak under the name of *Liquid Architecture*. Randall Packer and Ken Jordan in their book *Multimedia; From Wagner to Virtual Reality r*eveals the concept of digital architecture through Novak's liquid architecture. In defining liquid architecture Packer and Jordan emphasize the idea of architecture for the sake of only digital medium. They state:

> Marcos Novak describes himself as a trans-architect, due to his work with computer-generated architectural designs, conceived specifically for the virtual domain, that do not exist in the physical world. His immersive, 3-dimensional creations are responsive to the viewer; transformable through user interaction ... Novak introduces the concept of liquid architecture, a fluid, imaginary landscape that only exists in the digital domain. Novak suggests a type of architecture cut loose from the expectations of logic, perspective, and the laws of gravity, one that does not conform to the rational constraints of Euclidean geometries. Novak's liquid architecture bends, rotates, and mutates in interaction with the person who inhabits it.[50]

According to Novak the relation between architecture and cyberspace is not simple and one-way. He claims that: "for the first time in history the architect is called upon to design not the object but the principles by which the object is generated and varied in time."[51] This points out a very significant aspect of digital architecture and he calls this architecture as liquid, dematerialized architecture. Bernard Cache similarly suggests an explanation for this in his essay, *Framing the Fold: Furniture Architecture, Geography, and the Pursuit of the Virtual*, stating that this can be achieved through "computational model of design."[52] According to Cache:

---

[49] Hani Rashid and Lise Anne Couture, 2002, *Asymptote: Flux* (London: Phaidon,) p. 50. [emphasis mine]

[50] Marcos Novak, 1991, "Liquid Architecture", eds., Randall Packer and Ken Jordan, 2002, *Multimedia; From Wagner to Virtual Reality*,W.W, (Norton, New York) [Internet, WWW,] ADDRESS: http://www.artmuseum.net/w2vr/timeline/Novak.html [Accessed: 20 Aug 2004]

[51] Marcos Novak, 1991, "Liquid Architectures in Cyberspace", in Michael Benedikt, ed., *Cyberspace: First Steps* (Cambridge: The MIT Press), p. 251.

[52] Bernard Cache, 1998, "Framing the Fold: Furniture Architecture, Geography, and the Pursuit of the Virtual", John Beckmann (Eds.), *The Virtual Dimension* (New York: Princeton Architectural Press). p.302

> [...] there are architects who draw a sketch on paper and give it to other people who just enter them into the computer. The computer allows nothing more than a translation, nothing more than what can be done with a pencil. [...] But if you start using the computer as a conceptor, and if we become something more than simple operators, real possibilities begin to emerge.[53]

So, Cache, whose creations are not based on drawing but based on "formulae and analytic functions,"[54] suggests that "we must learn to think with the computer in mathematical terms; we must develop mathematical formulae and not use the computer to pick points."[55] This is stated to be possible when the operator of the computer and the designer are the same. For him this is what would allow the designer to think with the computer. Each formula would end up with a new image triggering creativity and reproduction. This is a solution he found within his own methodology.

In this framework, architects build the algorithm, algorithmic relations and systematic of all the processes, which are possible within the VR environment. In his essay *Liquid Architectures in Cyberspace,* Novak refers to the comprehensive meaning of Liquid Architecture as follows:

> Cyberspace calls us to consider the difference between animism and animation, and animation and metamorphosis. *Animism* suggests that entities have a spirit that guides their behavior. *Animation* adds the capability of change in location, through time. *Metamorphosis* is change in form, through time or space. More broadly, metamorphosis implies changes in one aspect of an entity as a function of other aspects, continuously or discontinuously *I use the term liquid* to mean *animistic, animated, metamorphic...*[56]

The relation between animation and metamorphosis, which Novak referred above, is important to understand a crucial property of digital architecture. Metamorphosis is not a simple animation; it is a change in location through time. It includes a change in form as well. This is an important opportunity offered by cyberspace.

---

[53] Ibid., p.302

[54] Ibid., p.302

[55] Ibid., p.302

[56] Marcos Novak, 1991, "Liquid Architectures in Cyberspace", in Michael Benedikt, ed., *Cyberspace: First Steps* (Cambridge: The MIT Press), p. 250.

Digital architecture, having its own reality and parameters, creates virtual environments in cyberspace. These parameters are being free of limitations, being based on algorithmic and relational thinking, allowing for complex mathematical operations. Cyberspace constitutes an appropriate medium for optimum orientation and navigation within the information environment. Information is not static and material but it is the major force changing the environment. Digital architecture is not only for information; it is also reshaped and redefined by information. Information environments in digital space serve as extensions to physical spaces and supplement them through a new understanding of architecture. As stated by Bermudez and King:

> The actual and potential markets include gaming and entertainment developments, art installations, educational applications, and research. These markets provide architects the opportunity to participate in the design of 3D gaming environments, educational software, architecture for public experience and entertainment, data representation, cyberspace and virtual reality studies, and other digital services which will be required for this new world... Digital environments will not replace the built environment as a major architectural market, but they will significantly complement it, thus strengthening the entire architectural profession.[57]

2.4 Examples of Digital Architecture

For a further understanding of digital architecture some of *representational* examples in digital environment will be elaborated here to clarify the difference with the definition claimed by the thesis. .

2.4.1 The Virtual Campus

The Virtual Campus (VC)[58] in the Faculty of Architecture at the University of Sydney is an example of digital architecture that re-constructs 3D spatial layout of the campus virtually. It allows the users to reach several environments, such as, office, classroom, conference buildings, etc. The VC is divided into several functional areas. It enables users to go to a specific place or way out.

---

[57] J. Bermudez and K. King, 1995, "Architecture in Digital Space: Actual & Potential Markets," Kalisperis & Kolarevic (eds.), *ACADIA 1995* (Seattle, WA: University of Washington), pp. 405-423 [Internet, WWW]. ADDRESS: http://www.arch.utah.edu/people/faculty/ julio/cyber2. htm, [Accessed: 20 Aug 2004] [emphasis mine]

[58] see http://www.arch.usyd.edu.

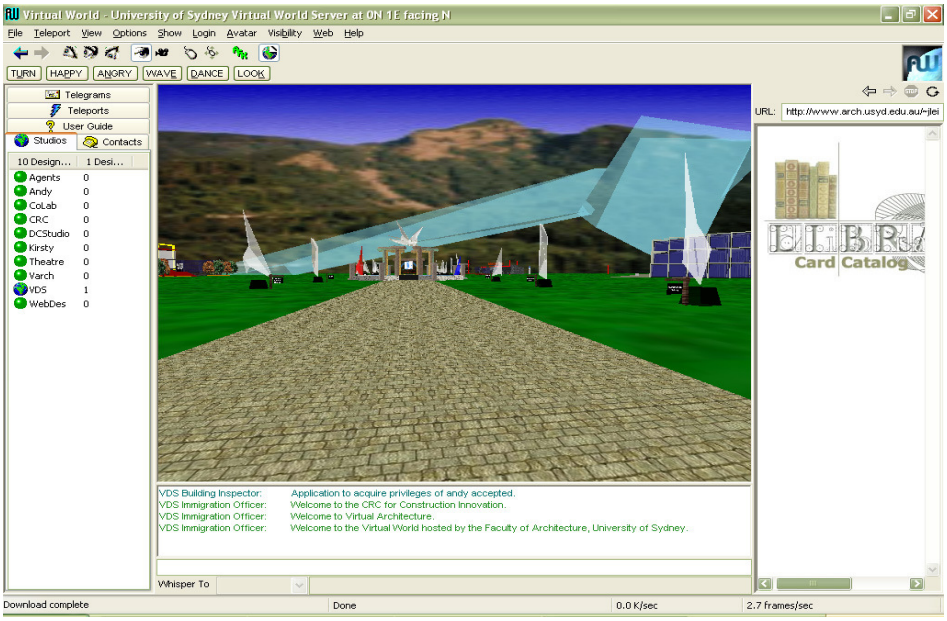

Figure 2.4 Exterior Image of Virtual Campus (Source: Mary Lou Maher, 2004, *Designing Virtual Architecture: Examples and Principles*, [Internet, WWW, PPT]. ADDRESS: http://www.arch.usyd.edu.au/~mary/DESC9103/DesignVWs.ppt [Accessed: 30 Dec 2004] p.14)

There are five major functional buildings, which consist of several rooms in the VC; The Classroom Building contains all the required rooms for education. The rooms are specified according to the subjects being taught. The Office Building contains the offices of the academic staff and students. An office can be provided as a standard office or each office can be designed for a particular person. The Conference Building contains seminar rooms and studios for presentations and discussions. The Resources Building contains various rooms like library, documentation etc. The Professional building contains office space for professional organizations.[59]

The entrance to the VC is through the courtyard. The courtyard is visualized as a 3D model of the entire campus. Buildings are presented in web browsers. As it is shown in figure below the conference room is designed for seminar representations.

[59] Mary Lou Maher, Nıng Gu and Feı Lı, (2001),Visualisation and Object Design in Virtual Architecture quoted in J. S. Gero, S. Chase and M. Rosenman (eds), *CAADRIA2001*, Key Centre of Design Computing and Cognition, University of Sydney, pp. 39-50. [Internet, WWW,PDF]. ADDRESS: http://www.arch.usyd.edu.au/~chris_a/MaherPubs/2001pdf/CAADRIA01.pdf [Accessed: 17 Dec 2004] p.5

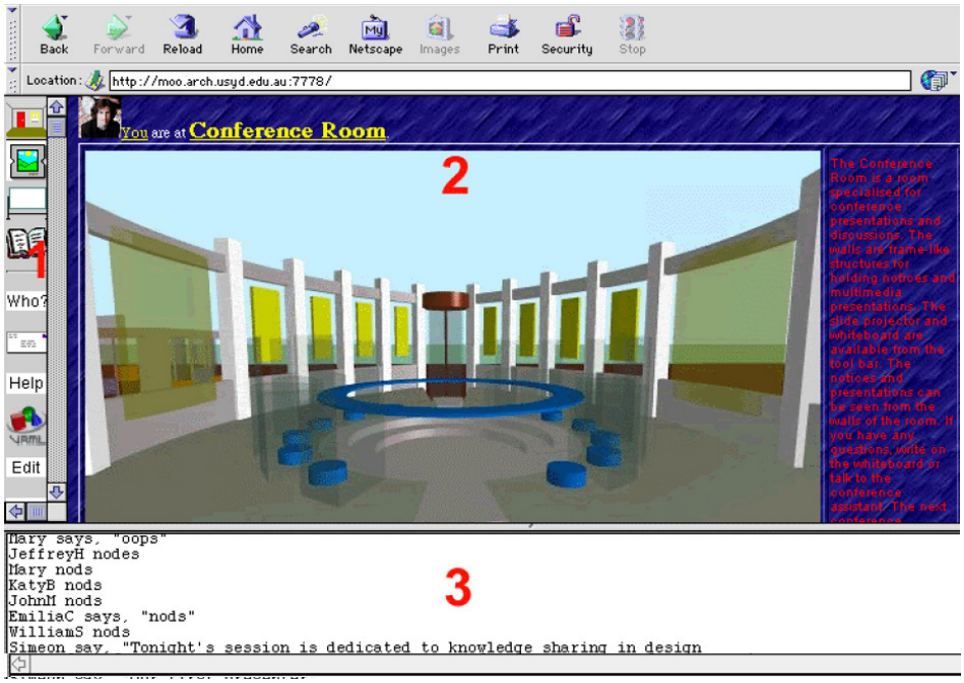

Figure 2.5 Conference Building in Virtual Campus (Source: M.L. Maher, S. Clark and S. Simoff, *Learner Centred Virtual Environments as Places*, [Internet, WWW, PDF]. ADDRESS: www.arch.usyd.edu.au/~mary/Pubs/2001pdf/ECSCL.pdf [Accessed: 30 Dec 2004] p.4)

The virtual campus, which is mentioned in *Designing the Virtual Campus,* can be accepted as a kind of "Multi User Virtual Environment"[60] (MUVE) in which students can participate from both on and off-campus. It is evolved over time with the contribution of different people. Its design is somehow similar to the physical place but there are some differences in the design process. Maher, Bradford and Cicognani classified these differences in four:

> 1. While the design description is the documentation for the construction in the physical space, it is the design product at the same time in virtual space.
>
> 2. Modifying the design are numerous and quick.
>
> 3. The design reasoning focuses on functionality of spaces rather than on the geometry of the space.
>
> 4. The traditional use of geometry to place and organize rooms is not the only way to think about the structure of the space. The rooms can be arranged according to

[60] M. L. Maher, B. Skow and A. Cicognani, 1999, "Designing the Virtual Campus", *Design Studies* 20(4), pp.335-336

functional requirements or hierarchical way. [61]

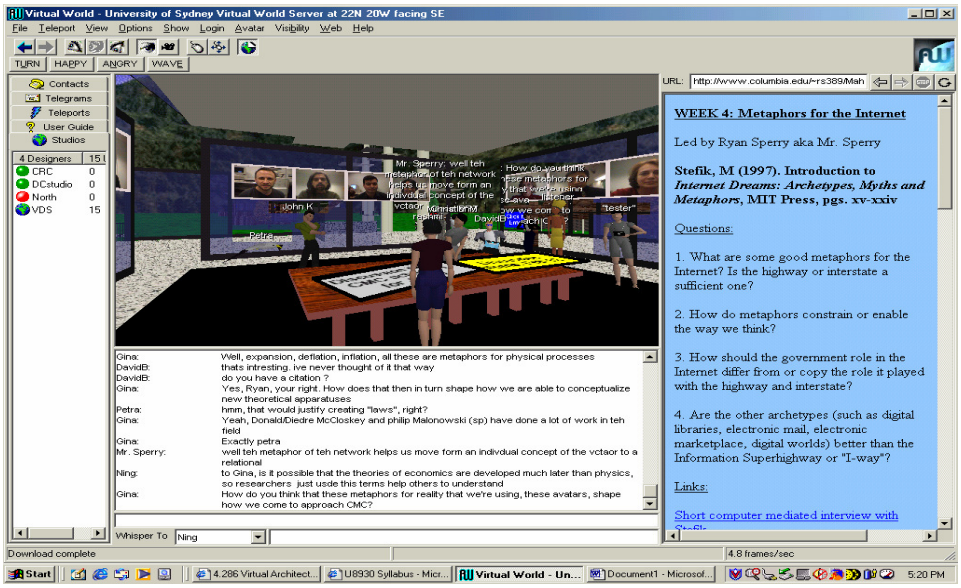

Figure 2.6 User interaction in Virtual Campus (Source: Mary Lou Maher, 2004, *Designing Virtual Architecture: Examples and Principles*, [Internet, WWW, PPT] ADDRESS: http://www.arch.usyd.edu.au/~mary/DESC9103/DesignVWs.ppt [Accessed: 30 Dec 2004] p.4)

Virtual campus can be analyzed by the four tools, offered by the thesis, namely visualization, navigation, interaction and data integration. Utilization of architectural and abstract metaphors enhanced the visualization by modification of spaces according to the density of users. That is, when the user number increases, the space dimensions increase accordingly. Also the user can change the properties of space according to the function of use. The virtual campus situation also refers to the features of navigation and interaction. The understanding of navigation can be seen in links and as well as in hallways and ramps in 3D modeling. All communication means in the environment can be characterized into the criteria of interaction, i.e students' dialogues between peers and instructors, teleconferences, attending to the virtual classes.

[61] Ibid., p.336

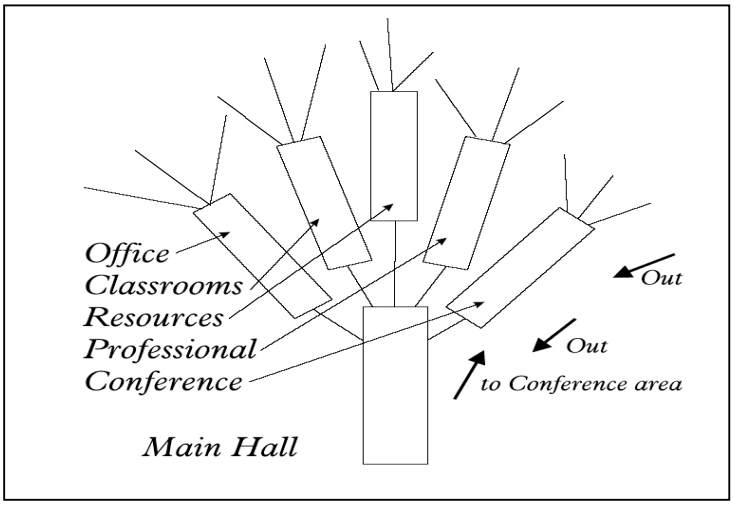

Figure 2.7 The Place representation as an object hierarchy in Virtual Campus (Source: Mary Lou Maher and Fei Li, 2000, *Representing Virtual Places - A Design Model for Metaphorical Design* [Internet, WWW, PDF] ADDRESS: http://www.arch.usyd.edu.au/~mary/Pubs/2000pdf/ACADIA2000.pdf [Accessed: 30 Dec 2004] p.5)

2.4.2 Tappedin

Tappedin[62] is a virtual "educational environment" which is specifically created for "teacher development."[63] Tappedin environment (building) is mainly based on links, which navigates the users to the virtual places. The orientation within the building is done by vertical circulation elements, by elevators, and one can reach the desired information by "clicking on a word or icon." Maher and Li mention that:

> In a room of Tappedin, there are names on the floor plan images that are active links… Most of these names stands for the exits and links to other areas. There are also names that stand for often used objects and names that link to a web site. In Tappedin there are also some things that don't have any substantial use but create ambience. For example; "Red Table" and "Blue Table" in the "ED oasis library" and the table, chairs and plant.[64]

[62] see http://www.tappedin.org

[63] Schlager, M., Fusco, J. and Schank, P. (1998). Cornerstones for an online community of education professional, *IEEE Technology and Society*, 17(4):15-21. quoted in Mary Lou Maher and Fei Li, 2000, *Representing Virtual Places - A Design Model for Metaphorical Design* [Internet, WWW,PDF].ADDRESS: http://www.arch.usyd.edu.au/~mary/Pubs/2000pdf/ACADIA2000.pdf [Accessed: 17 Dec 2004], p.3

[64] Mary Lou Maher and Fei Li, 2000, *Representing Virtual Places - A Design Model for Metaphorical Design* [Internet, WWW,PDF].ADDRESS: http://www.arch.usyd.edu.au/~mary/Pubs/2000pdf/ACADIA2000.pdf [Accessed: 17 Dec 2004], pp.3-4

Figure 2.8 Visual representation of place in Tappedin (Source: Mary Lou Maher and Fei Li, 2000, *Representing Virtual Places - A Design Model for Metaphorical Design* [Internet, WWW, PDF] ADDRESS: http://www.arch.usyd.edu.au/~mary/Pubs/2000pdf/ACADIA2000.pdf [Accessed: 30 Dec 2004] p.4)

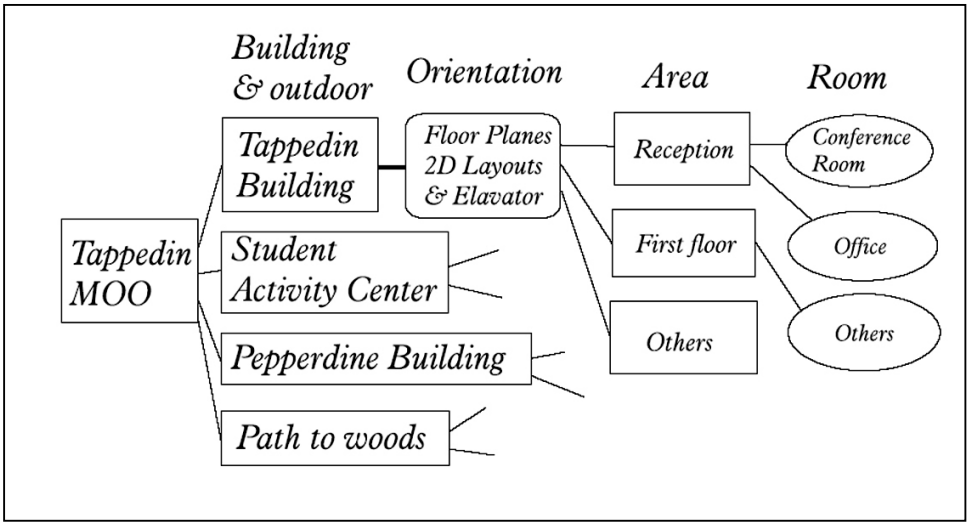

Figure 2.9 Place representation as an object hierarchy in Tappedin (Source: Mary Lou Maher and Fei Li, 2000, *Representing Virtual Places - A Design Model for Metaphorical Design* [Internet, WWW, PDF] ADDRESS: http://www.arch.usyd.edu.au/~mary/Pubs/2000pdf/ACADIA2000.pdf [Accessed: 30 Dec 2004], p.4

All the specific rooms are being controlled and divided into specific classes. Maher and Li state that "this layered object-oriented structure of place representation is useful because it simplifies the process of maintaining, designing and redesigning the VP [virtual place]" [65]

2.4.3 Trace City

Florian Wenz and Fabio Gramazio are famous for their virtual project, Trace City.[66] Trace city is an environment where all the information can be grasped by only clicking them by mouse. The space is being shaped by the movement of visitors. For instance the corridor appears, when the visitor gets in. When he/she passes it, the corridor disappears till the use of other visitor. The corridor appears at the time of navigation. According to Gerhard Schmitt "The visitor intuitively perceives the shape of the underlying surface during navigation while never actually seeing it." [67] That is, there is an interaction between one visitor and the other visitor, and between the visitor and environment. In his book, *Information Architecture*, Schmitt describes this project as:

> …An interactive computer installation. There was purposely no attempt to reconstruct visionary city models of the past. *TRACE* was built to present and test ideas concerning the virtual aspects of cities. The location of the city is the Internet, the material is information, the builders and inhabitants are the visitors of the exhibition… TRACE originates from the energy or motivation of the visitors to present themselves in the environment, to leave traces and to read and interpret traces of previous visitor [68]

---

[65] Ibid., pp.4-5

[66] see "Archeology of the future city", http://caad.arch.ethz.ch/trace

[67] Gerhard Schmitt, 1999. *Information Architecture: Basis and Future of CADD.* Trans. Lucinda Byatt. (Basel; Boston; Berlin: Birkhauser) p. 76

[68] Ibid., p.76

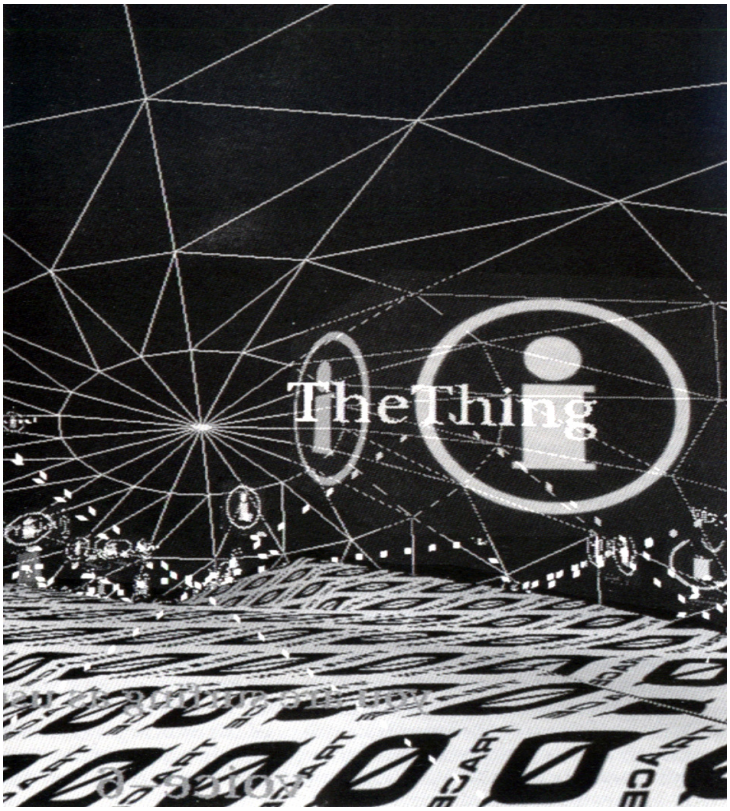

Figure 2.10 An OutWorld View in Trace, Florian Wenz and Fabio Gramazio, 1996. (source: Gerhard Schmitt, 1999. *Information Architecture: Basis and Future of CADD.* Trans. Lucinda Byatt. (Basel; Boston; Berlin: Birkhauser) p.43)

As can be understood from the above explanations, Trace City is an important example for data environment.

All digital environments which are mentioned above are the crucial examples of obtaining information through digital medium. The examples are selected from different types of use but all of them have a common important aspect with their architectural design concepts which the visualization, navigation, interaction, and data integration take place in every orientation.

Figure 2.11 An InWorld View in Trace, Florian Wenz and Fabio Gramazio, 1996. (source: Gerhard Schmitt, 1999. *Information Architecture: Basis and Future of CADD.* Trans. Lucinda Byatt. (Basel; Boston; Berlin: Birkhauser) p.77)

CHAPTER 3

A FRAMEWORK TO ANALYZE DIGITAL ARCHITECTURE

The research on cyberspace and VR has affected and changed the agenda of architecture as discussed on the previous chapter. So, as stated by Paul Virilio, the studies for virtual reality "tend to extend real space of architecture toward virtual space."[69]

Digital architecture functions in multi-dimensional virtual environments. When architecture is considered, "spatiality" becomes the major aspect of discussion.

Cyberspace offers digital architecture a flexible medium for the spatial formation of information. Spatiality in information environment means "the representation of data as a collection of objects in space… in order to make data easier to comprehend and manipulate."[70] Spatiality refers to the architectural design of a 3D model in digital space. Information is integrated into this digital space. By doing so, it is not the information itself but the presentation of information which is materialized in the digital medium. The design of the digital space and the introduction of its spatial qualities bring the issue of information architecture into discussion.

Based on the familiarity of human beings with spatiality in physical environments, data environments in cyberspace are to be designed in a spatial formation. This is due to the fact that the perceptual processes utilized in understanding virtual environments are the same with those that are used in understanding physical ones. For the thesis,

---

[69] Andreas Ruby, October 1993, "Architecture in the Age of Its Disappearance - An Interview with Paul Virilio", John Beckmann, ed., 1998, *The Virtual Dimension* (New York: Princeton Architectural Press), p.182.

[70] *Microsoft Press® Computer and Internet Dictionary ©,* 1997, 1998, 1999, Microsoft Corporation, All rights reserved. [CD-Rom]

spatialization of information in digital medium; in other words architecture of and for the information in digital environments is analyzed through visualization, navigation, interaction and data integration.

The framework of analysis is developed in reference to the studies of Mary Lou Maher and Julio Bermudez together with Jim Agutter and Dwayne Westenskow. In her study, Maher focuses on the design of the environment through digital architecture, and draws a general framework for the analysis of 3D virtual environments. However, Bermudez, Agutter and Westenskow focus particularly on the representation of information in digital medium. The framework of analysis is developed as a synthesis of these two studies.

3.1 The Analysis of 3D Virtual Architecture by Mary Lou Maher

In her article *Virtual Architecture*, Maher emphasizes three aspects for the analysis of 3D virtual environments, which are "visualization", "navigation" and "interaction."[71]

Maher explains "visualization" as the "application of metaphors, forms and other visual aspects."[72] She refers to two types of application of metaphors in her study: architectural metaphors and abstract metaphors. Architectural metaphor refers to making analogies to physical spaces; forms and materials from the physical world are being used. On the other hand, abstract forms, which do not necessarily exist in the physical world, can be used. These forms can also be free from physical constraints.

[71] Mary Lou Maher and Ning Gu, 2004, *Virtual Architecture*, [Internet, WWW,PPP].ADDRESS: www.arch.usyd.edu.au/~mary/DESC9103/va_intro.ppt [Accessed: 17 Dec 2004] p.29

[72] Ibid.

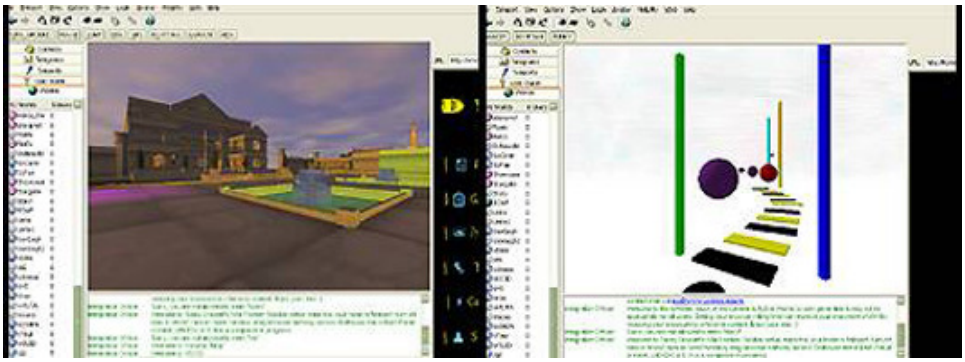

Figure 3.1 Architectural and Abstract Metaphors (source: Mary Lou Maher and Ning Gu, 2004, *Virtual Architecture*, [Internet, WWW, PPP] ADDRESS: www.arch.usyd.edu.au/~mary/DESC9103/va_intro.ppt [Accessed: 17 Dec 2004] p.30)

Maher explains "navigation" as "selecting and arranging way finding aims and hyper links."[73] Elements of "way finding" are spatial elements like paths, openings, hallways, stairs, intersections, landmarks, maps, signs and etc. Hyper links, which are unique in virtual environments, are categorized in two: "Teleport portal and Warp portal." [74] Teleport portal refers to a hyper link that takes avatars from one location to another location *without* transition. Warp portal refers to a hyper link that takes avatars from one location to another location *with* transition.

Coming to "interaction," Maher explains "interaction" as the ascription of behaviors, designing how behaviors are activated and combined. She categorizes activating behaviors as follows:

1. Activating Behaviors in 3D Virtual Architecture

    - Mouse-click: intentional, occupants are expecting some consequences.
        - Designers allow occupants to have certain degrees of control over the interactions with the environment.
    - Bump (especially with hidden objects): accidental, occupants encounter the interactions unexpectedly.
        - Designers express design intentions more assertively.

[73] Ibid., p.29

[74] Ibid., p.34

2. Interaction in 3D Virtual Architecture

- Carefully ascribe behaviors to different 3D models of virtual architecture.
- Decide how the behaviors are activated and connected with each other.
- Therefore, one interaction between the occupants and the environment can activate other subsequent interactions. [75]

3.2 "Data Representation Architecture" by Julio Bermudez, Jim Agutter and Dwayne Westenskow

In their paper, *Data Representation Architecture: Visualization Design Methods, Theory and Technology Applied to Anesthesiology*, Bermudez together with Agutter and Westenskow present problems of the existing methodology that is being employed in ongoing multidisciplinary data visualization research in anesthesiology. The project's main goal is to develop a new data representation technology to visualize physiologic information in real time. They state that "using physiologic data, 3-D objects are generated in digital space that represent physiologic changes within the body and show functional relationships that aid in the detection, diagnosis, and treatment of critical events."[76]

The paper reports an interdisciplinary research project dealing with this undeveloped area of medical imaging: the visualization of physiologic data. The goal is to create a new visualization model and technology for physiologic change based on:

1. a new *formal semiotics* using basic principles, elements and systems of graphic depiction. This implies the development of graphic conventions to make possible the translation and understanding between numerical parameters and images or shapes.

[75] Ibid., p.37

[76] Julio Bermudez, Jim Agutter and Dwayne Westenskow, 2000, "Data Representation Architecture: Visualization Design Methods, Theory and Technology Applied to Anesthesiology." *ACADIA 2000.* [Internet, WWW,] ADDRESS: http://www.arch.utah.edu/people/faculty/julio/acadia2000.pdf [Accessed: 20 Aug 2004] p.1

2. *data integration*; the design of a multimodal virtual environment that expresses relationships among separate sets of measured data may not only reveal critical states more efficiently and quickly than isolated representations, but also point at conditions that may not be apparent in separate displays of data.

3. *interactivity*; the new model needs to allow the user to dynamically work with the data through diverse hierarchical layers, hyper-representations, and various multimodal formats. Easy and natural interface with data supports better understanding of the ongoing situation and improves performance.[77]

What Bermudez, Agutter and Westenskow refer to as "formal semiotics" is referred as "visualization" by Maher, and what Bermudez, Agutter and Westenskow refer to as "interactivity" is referred as "interaction" by Maher.

More specifically, creation of this visualization model by Bermudez involves the following steps:

1. analyzing known physiologic phenomena to be monitored, including desirable (i.e., normal) and undesirable states;

2. analyzing the anesthesiologist's decision making process, including acquired behaviors and group influence;

3. analyzing all available variables and relations or functional dependencies among them, and prioritizing their inclusion into the application;

4. developing a conceptual model representing the critical functions to be monitored, including the relationships among their variables (user's mental model);

5. analyzing and defining essential semiotics of 2D and 3D design based on existing research on human factors, cognitive psychology and architectural and design theory;

6. formulating a visual design whereby 3D objects, attributes, spaces and frameworks follow the conceptual model;

7. designing software, with principles of modularity and distribution over networks;

8. testing the design and software with users. [78]

[77] Ibid., p.3

[78] Ibid., p.7

The team working on the model applies following seven design premises to guide its data visualization design process:

1. inventing a formal semiotics to link graphics and physiologic meaning;

2. integrating data so that representations reveal data's relationships and interactions;

3. providing interactivity to facilitate user's access to the information;

4. mapping information into a 3D data representation architecture in order to improve recognition while supporting data integration and significant increases in the number of variables to be displayed;

5. using an ordinary PC platform to insure universal adaptability and adoption in medical settings;

6. allowing network distribution to support data visualization as well as raw data access at any distance (at moderate bandwith);

7. aiming at formal, functional, and technical simplicity. [79]

The result of the project is shown in the Figures 3.2 and 3.3 presenting a comparison of the current display and the new visualization system of displaying data in 3D format. The same data is displayed in four interactive windows; each one designed to show certain information in detail.

[79] Ibid., p.8

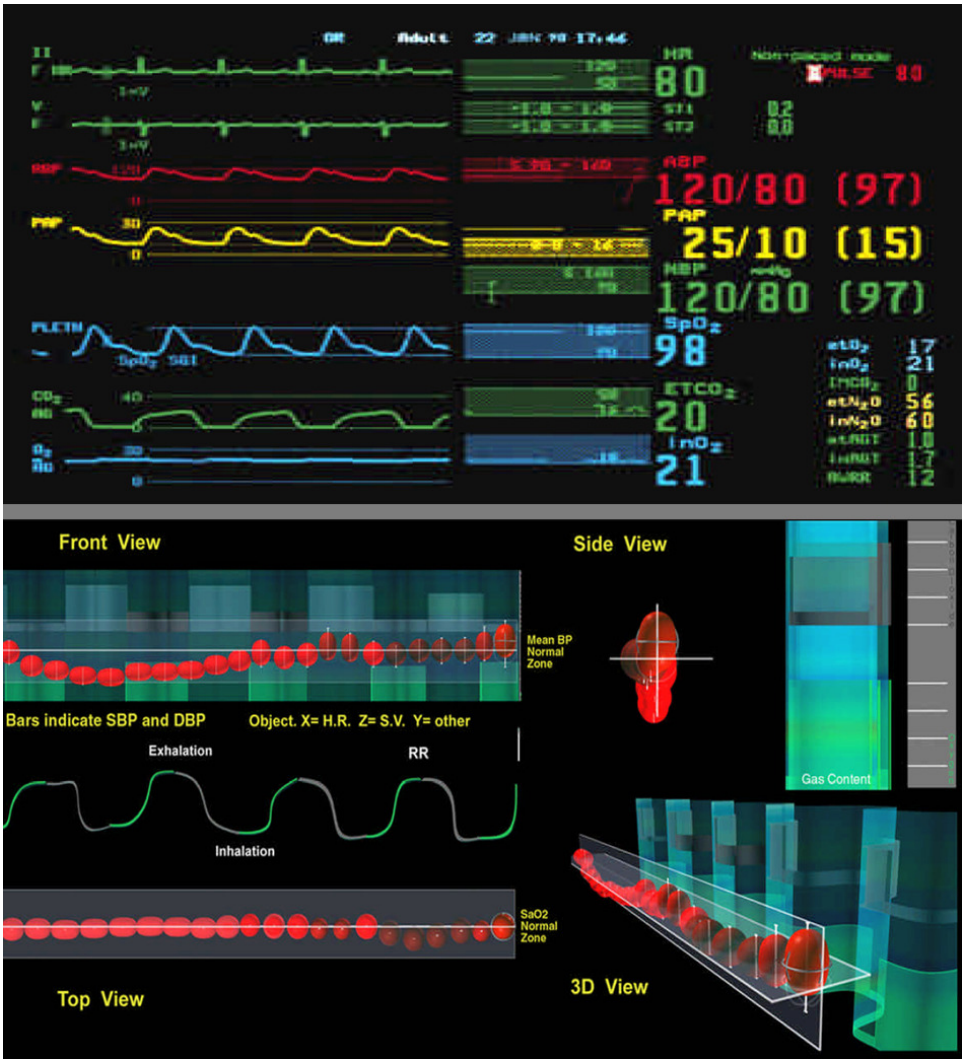

Figure 3.2 (top) Current Display of Physiologic Data (Hewlett Packard, Rockville, MD) (source: Julio Bermudez, Jim Agutter and Dwayne Westenskow, 2000, "Data Representation Architecture: Visualization Design Methods, Theory and Technology Applied to Anesthesiology." *ACADIA 2000* [Internet, WWW,] ADDRESS: http://www.arch.utah.edu/people/faculty/julio/acadia2000.pdf [Accessed: 20 Aug 2004] p.4)

Figure 3.3 (bottom) New Visualization System for Displaying Physiologic Data (source: Ibid., p.9)

3.3. Framework of Analysis for Asymptote's 3DTF VRE

The framework of analysis for NYSE project offered by the thesis is developed in reference to the studies of Mary Lou Maher and Julio Bermudez, Jim Agutter and

Westenskow. On the basis of this framework, the study aims to understand how information is spatialized, how architecture of and for information is created in Asymptote's project in terms of:

1. Visualization
2. Navigation
3. Interaction
4. Data Integration

3.3.1 Visualization

In computer terminology it refers to "a feature of an application that displays data in the form of a video image. For example, some databases can interpret and show data in the form of a two or three-dimensional model."[80] The thesis refers to "visualization" as the usage of visual features or usage of metaphors for clarity and ease of comprehension. In this way vast amount of information can be organized and presented in such a way to facilitate perception and interpretation.

As the amount of accumulated information increases, the difficulty to access, view, display, modulate and correlate them arises. This requires a certain design of the information environment in the form of real world representations. Bermudez, Agutter and Westenskow also state a need for a certain design and format of display in the information:

> Case studies, Human Factors and Cognitive Sciences have shown that the human mind deals better with information complexity when data is displayed in *graphic, real-world analog representations rather than in text-based or numerical representations.* Additional research in thinking, imagination, ideation, and learning has repeatedly shown that visualization plays a sophisticated and essential yet intuitive role in helping us associate, manipulate and infer information.[81]

---

[80] *Encarta® World English Dictionary* ©, 1999, Microsoft Corporation, All rights reserved, Developed for Microsoft by Bloomsbury Publishing Plc. [CD-Rom]

[81] Julio Bermudez and Jim Agutter, 2000, "Data Representation Architecture: Visualization Design Methods, Theory and Technology Applied to Anesthesiology," *ACADIA 2000,* [Internet, WWW,] ADDRESS: http://www.arch.utah.edu/people/faculty/julio/acadia2000.pdf [Accessed: 20 Aug 2004] [emphasis mine] p.2

Easing perception is critical in the experience of digital architecture. Marcos Novak concentrates on the key factors that ease perception. He reveals these factors as follows:

> Architecture, most fundamentally, is the art of space… there are three fundamental requirements for the perception of space: reference, delimitation and modulation. If any one is absent, space is indistinguishable from non-space, being from nothingness… this suggest that cyberspace does not exist until a distance can be perceived between subject and boundary, that is to say until it is delimited and modulated… a space modulated in a way that allows a subject to enter and inhabit it is called architecture.[82]

Since the users have to utilize the same processes in perceiving physical spaces; architecture has to play a critical role in designing virtual information environments so as to facilitate perception via building spatiality in digital space. According to Bridges and Charitos, "virtual environment is being experienced via the same perceptual processes that are employed for perception in the real world."[83] As they mention, "the design of virtual environment comprises several spatial entities and events that accommodate human activities such as navigation, interaction and communication."[84]

Bridges and Charitos believe that the design of virtual environment can be seen as "an architectural problem and it may benefit from the existing architectural design knowledge."[85] This contribution may range from creating legible environments to "the problem of how to compose form in order to accommodate function and convey meaning."[86] The thesis argues that it is digital architecture through which the design of these legible environments should be achieved.

An important concept in designing information space for a convenient visualization is the usage of spatial metaphors: architectural or abstract.

---

[82] Marcos Novak, 1991, "Liquid Architectures in Cyberspace", in Michael Benedikt, ed., *Cyberspace: First Steps* (Cambridge: The MIT Press), p. 243

[83] A. Bridges, D. Charitos, 1997, "On architectural Design in Virtual Environments", *Design Studies* 18, p.144

[84] Ibid., p.145

[85] Ibid., p.145

[86] Ibid., p.149

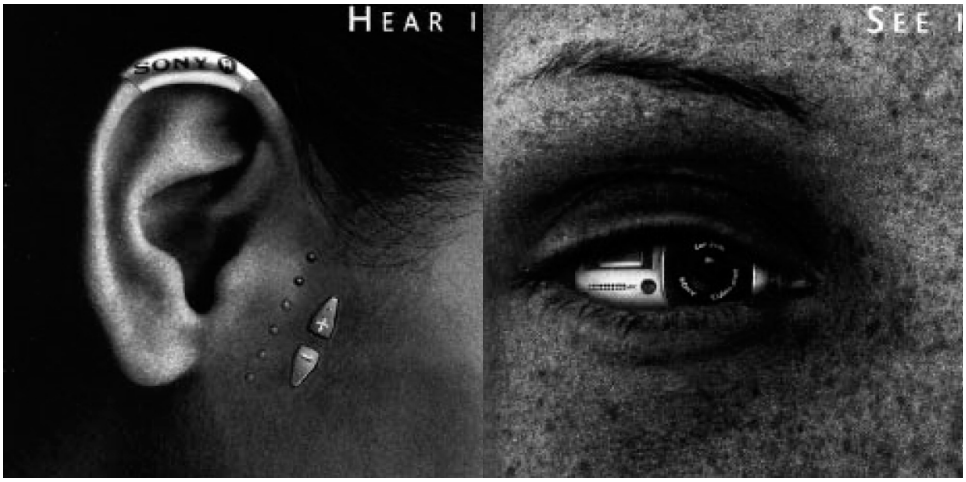

Figure 3.4 Virtual Environment is Being Experienced via the Same Perceptual Processes that are Employed for Perception in the Real World but the Processes of Creation of Stimuli is Changing (Source: *Virtual Places: Architecture and Urbanity in the Age of Electronic Media,* [Internet, WWW, PDF] ADDRESS: homepage.mac.com/bogronlund/3_314_2003IDv3.pdf [Accessed: 30 Dec 2004] p.2)

Architectural metaphor refers to making analogies to physical spaces; existing forms and materials from physical world can be used. The design of the virtual environment may be in agreement with the physical rules and consist of figures from physical world, for instance there can be a building firmly sitting on the ground, and mountains, hills and sky at the background of the 3D virtual model.

On the other hand, abstract metaphors, which do not necessarily exist in physical world, can be used. These forms can also be free from physical constraints; i.e. flying objects. For instance, a figure, which looks like steps of staircase might not even be attached to each other but may symbolize the route of an digital environment.

Since there are no physical constraints like gravity, construction materials or environmental conditions in virtual environments, there is no functional necessity to imitate the real world architectural elements like column, roof or window. For Bridges and Charitos, "in the design of virtual environments formal detail should be added in an abstract way when it serves some purpose, especially for designing meaningful and

convincing spaces."[87]

Meredith Bricken emphasizes the importance of metaphors in the design of virtual environments. For Bricken, metaphors can be used as organizing elements.[88] She concludes by saying that "as much as a virtual world seems familiar to us from some real-world experience, we can build the cognitive model easily and we may accommodate to it more quickly."[89] As an example to this principle; MUVEs can be given.

M. L. Maher, Skow and Cicognani in their essay *Designing the Virtual Campus* state that, "MUVEs [Multi User Virtual Environment] are computer environments that use a metaphor of physical space and place".[90] So, as it is mentioned in the same essay, "being in a MUVE is much like being in a building."[91] In a MUVE there are virtual rooms, some restrictions, rules and preferences.

Coming back to the importance of spatiality and visualization; as is stated by Peter Anders, "We think with space. Using our mind's ability to dimensionalize information, we reduce complexity to manageable units –objects- of information... The mind uses spatial thought to manage incoming information, reducing its complexity for our use…"[92] Dimensionalizing information, within a spatial formation, can be achieved via digital architecture with illustrative materials like charts, interactive 3-D graphics, video displays.

---

[87] A. Bridges, D. Charitos, 1997, "On architectural Design in Virtual Environments", Design Studies 18, p.150

[88] Meredith Bricken, "Virtual Worlds: No Interface to Design", in Michael Benedikt, ed., 1991, *Cyberspace: First Steps* (Cambridge: The MIT Press), p.369

[89] Ibid., p.377.

[90] M. L. Maher, B. Skow and A. Cicognani, 1999, "Designing the Virtual Campus", *Design Studies* 20(4), p.322

[91] Ibid., p.323

[92] Peter Anders, 1999, *Envisioning Cyberspace*, (NY: McGraw-Hill,) p.9-10

N. Gershon, S.G.Eick and S. Card, in their essay *Information Visualization,* refer to the significance of information visualization and the representation of it through visual metaphors as follows:

> Information visualization focuses on information, which is often abstract. In many cases information is not automatically mapped to the physical world (e.g. geographical space). This fundamental difference means that many interesting classes of information have no natural and obvious physical representation. A key research problem is to discover new visual metaphors for representing information and to understand what analytical tasks they support.[93]

As is stated by them, it is significant to utilize new representations of information for better illustration and perception as well as for supplementing analytical tasks in this information environment.

3.3.2 Navigation

Besides visualization aspects, navigating in this environment is another critical factor for digital architecture. "Navigation" in a virtual environment can be achieved via two ways.

The first one is way-finding. This can be managed in two ways: either by walking through paths, hallways or stairs as is the case in physical space or by flying which is not possible for human beings in physical space.

The second type of navigation is via hyperlinks, which are specific to virtual environments. These hyperlinks help the user to change location. Via this property of virtual environments, the users surpass the time and space constraints in physical environments reaching to required locations in a few seconds.

[93] N. Gershon, S.G. Eick and S. Card, 1998, "Information Visualization," *Interactions*, in Martin Dodge and Rob Kitchin, 2001, *Mapping Cyberspace*, (NY; London: Routlege,) p.107

3.3.3 Interaction

"Interaction" is another aspect, which contributes to the spatiality of the information environment. It refers to the user and the machine having an effect on each other. This allows for information communication to the user based on the instruction given by the user through activating behaviors like mouse clicks. In order to achieve interaction in cyberspace, certain behavior patterns are programmed into the 3D models. The ways of activating and interconnecting behaviors are also defined within the modeling. This way of interaction between the user and the environment can activate other interactions. The environment responds to users instructions. For instance, in a digital financial market model, by programming the behaviors and the interaction between behaviors into the models, a click can enable the user to buy a bond or a stock and deduct the cost from the users balance.

3.3.4 Data Integration

"Data integration" is the final aspect when the architecture of and for information is under consideration.

As it has been stated in the previous pages, data integration means the organization of data in a consistent and coordinating way to constitute a balanced whole. Real time information is not only solely presented in this environment but also the synchronization within data changes is enabled in the model. Any change in a particular data leads to the immediate change in a related data or group of data, and in turn a change in the environment itself. Data integration is the aspect, which constitutes the dynamism within the model.

CHAPTER 4

NEW YORK STOCK EXCHANGE VIRTUAL REALITY ENVIRONMENT BY ASYMPTOTE

This chapter will introduce and discuss New York Stock Exchange Three Dimensional Trading Floor Virtual Reality Environment (NYSE 3DTF VRE) designed by Asymptote. In order to better understand the project, and to illustrate the main argument of the thesis, Asymptote's approach to digital architecture will be introduced. In the analysis of this particular project, the aim is to understand the design processes by which information is spatialized, or in other words architecture for/of information is created in the digital environment.

4.1 Asymptote's Approach to Digital Architecture

To understand Asymptote's ideas on digital architecture, first of all, it is important to know what the word *asymptote* means. In their book, *Asymptote: FLUX,* Hani Rashid and Lise Anne-Couture describe the relation between the word *Asymptote* and their architectural thinking as follows:

> It [asymptote] is a mathematical term defining the infinite progression of a hyperbolic curve as it approaches an axis; in other words, an infinite meeting point of two converging lines, the vanishing point. This was an appropriate term for us because it symbolized the virtual meeting point of theory and practice, two things we are interested in bringing closer and closer together without actually contaminating one another, two autonomous trajectories. In 1995 Asymptote acquired another meaning for us that of the pursuit of both *virtual and real architecture* — again, two parallel tracks that meet at the infinite.[94]

More than a decade Asymptote stressed on technological developments in "media, collage, photographic techniques, digital modeling and imaging, video and

[94] Hani Rashid and Lise Anne Couture, 2002, *Asymptote: Flux* (London: Phaidon), p. 63. [emphasis mine]

multimedia."[95] In that sense, they claim that "as technology has evolved over the course of our practice we have sought to embrace its creative potential while intellectually and architecturally investigating its cultural and spatial implications."[96]

To indicate their approach, Rashid and Couture state, "Asymptote expands the boundaries of traditional architectural practice with work that ranges from buildings and urban design to gallery installations and computer-generated environments."[97] They observe a huge potential in virtual architecture and refer to a potential interaction between physical and virtual architecture. On this subject they state:

> In both our professional and academic research we have been very interested in the potential of an architecture that brings together both virtual and real space. We have aimed to explore the possibilities of virtual architecture in terms of what it might inspire and bring to building in the physical world. The advent of digital technologies has not only provided us with new techniques and processes but also new realms for interaction and the deployment of architecture. Yet *virtual architecture and architecture based in the physical world are not necessarily mutually exclusive; our work continues to investigate and explore how one can affect and influence the other.*[98]

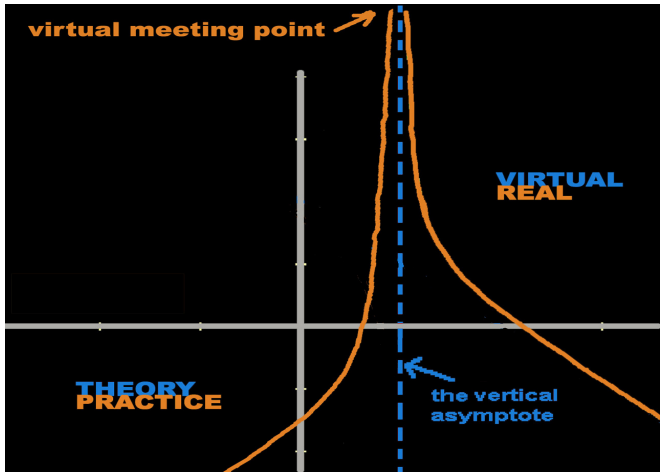

Figure 4.1 Representation of the Meaning of Asymptote (Halil Ayoğlu, 2004)

[95] Ibid., p. 5.

[96] Ibid.,p.5.

[97] Ibid., p. 1.

[98] Ibid., p. 5. [emphasis mine]

Asymptote's architecture can be defined as an interconnection between real and virtual spaces. In her essay, *Urban Drift*, Claudia Gliemann indicates that:

> His [Hani Rashid] projects Virtual Stock Exchange and Guggenheim Virtual Museum expand the existing institutions of the stock exchange and the museum by offering new possibilities of perception. The virtual designs are regarded *not as a substitute but as part of a new vision in which architecture too can assume digital forms. The architecture extends into digital space and takes possession of it: new terrain, new possibilities*.[99]

4.2 New York Stock Exchange 3D Trading Floor Virtual Reality Environment

The rapid developments in digital technologies bring forth cyberspace as an important medium. With the increased significance of information, the requirement for designing virtual information environments to supplement physical spaces has emerged. This was mainly due to the difficulty in reviewing, processing, storing, etc. vast amounts of information. This section of the thesis elaborates the emergence of information as a significant dimension and claims that NYSE 3DTF VRE is an extended digital information space augmenting the real NYSE by easily accessing, visualizing, storing, locating, correlating massive amounts of real time NYSE information. The control

unit of NYSE 3DTF VRE is Advanced Trading Floor Operations Center. This section will review how Asymptote accomplishes to present a clearer reinterpretation of actual NYSE real time information in virtual reality environment. (See Appendix for NYSE 3DTF VRE Facts)

Paul Virilio indicates that today there is a tendency towards dematerialization and disappearance in favor of information. In the past the matter was defined by its mass and energy, but today information becomes one of the dimensions of matter.[100]

---

[99] Claudia Gliemann, 1999, "Urban Drift," A*rchis* 1999, nr., 10, pp. 77-80, [Internet, WWW], ADDRESS: http://www.urbandrift.org/press/press_05.html [Accessed: 20 Aug 2004] [emphasis mine]

[100] Andreas Ruby, October 1993, "Architecture in the Age of Its Disappearance - An Interview with Paul Virilio", John Beckmann, ed., 1998, *The Virtual Dimension* (New York: Princeton Architectural Press,) p.180.

Similarly, in the book *Information Architecture*, Gerhard Schmitt points out that today "information should be declared the 5th dimension of architecture."[101] In his point of view, a huge amount of information is gathered during the design and construction stages of buildings and this information is stored and processed by computers in an effective way. So computer's potential as an external knowledge base for architecture should be recognized and "the mine of information, accumulated in databases, could be exploited and processed as a fifth dimension of architecture."[102] In fact, architecture starts to play a major role on solving the increasing complexity of controlling data and information.

Referring to this digital information space and its impacts to architecture; in his essay *Architectural Visions: Non-Verbal Essays on Cyberspace,* Bermudez states:

> …move towards 'informatization' has a parallel 'side effect': the dematerialization of architecture. For in order to increase the information carrying/broadcasting capacity of a medium (i.e. the architectural artifact), that medium must become informationally neutral, that is, it must lose its formal and material specificity so as not to be in the way of conveying information. Making an architecture of and for information requires an aesthetics and a language assuring total information neutrality, that is, a formal order based on purity, simplicity, and abstraction[103]

Bermudez refers to the involvement of architecture with the digital information spaces as: "… an 'architectonics of information', that is, the design of architectural objects and spaces that represent and organize information in cyberspace … the systematic *architecturization* of information and knowledge …"[104] What Bermudez stresses here is named as "spatialization of information" in this thesis.

---

[101] Gerhard Schmitt, 1999. *Information Architecture: Basis and Future of CADD.* Trans. Lucinda Byatt. (Basel; Boston; Berlin: Birkhauser) p. 9

[102] Ibid.

[103] Julio Bermudez, "Architectural Visions: Non-Verbal Essays on Cyberspace," Work presented at the 4th CyberConf, The Banff Centre for the Arts, Banff, Canada, 1994, *Collected Abstracts of the Fourth International Conference on Cyberspace.* (The Banff Centre for the Arts, Banff, Canada,) p. 19 [Internet, WWW,] ADDRESS: http://www.arch.utah.edu/people/faculty/julio/visions.htm [Accessed: 20 Aug 2004] p.3

[104] Ibid. [emphasis mine]

4.2.1 Aim of the Project

Increasing complexity of controlling data and information in the actual NYSE entailed a new project to accomplish changing demands. In order to find a solution to the complexity and difficulty of controlling daily real time information Asymptote was asked to design a (3D) digital space for information visualization. In that sense, Asymptote is asked to develop a new virtual, digital environment that would ease "the reading, correlation, and navigation of massive amounts of information."[105] Asymptote stresses on the changing demands on existing buildings. In consideration of new requirements of program, the virtual project aims to comprehend facilities that need to be re-handled and constructed in virtual environment. Asymptote focused on how to create the architecture of and for information since VR environment could serve as an extension of the actual NYSE.

Figure 4.2 General view from 3DTF (source: NYSE Web Environment, [Internet, WWW,] ADDRESS: http://marketrac.nyse.com/mt/index.html [Accessed: 30 Dec 2004]

[105] Hani Rashid and Lise Anne Couture, 2002, *Asymptote: Flux* (London: Phaidon,) p. 35.

4.3 Analysis of 3DTF

With respect to the aim of the project, NYSE 3DTF VRE is analyzed under four main criteria: 1) visualization, 2) navigation 3) interaction, and 4) data integration. These four criteria can be considered as primary constitutional elements of spatialization of information in digital cyberspace. In light of these criteria, which are specific to the digital architecture and explained in the previous chapter, the analysis part will discuss how the information space is created and how the architecture of and for information is realized in the case of NYSE VRE by Asymptote. The thesis mainly concentrates on the visualization of information where the goals are achieved via creation of a new visualization model and technology for changing real time data. Moreover the other three criteria are being analyzed as supportive elements to the understanding of cyberspace by visualization.

In regards to spatial dimension, the organization of this system, in fact, constitutes a 'spatial formation' in which the existing trading floor is rethought in virtual environment. In a way this new formation enables one to be able to inhabit a number of virtual spaces, scales, and points of view at the same time.

4.3.1 Visualization

Visualization applies basic principles and systems of graphical representations and three-dimensional visual aspects. This implies the development of text based, graphic conventions and multi dimensional virtual environment to make the translation and understanding between numerical financial parameters and images or shapes along with economic events possible. This is mainly aimed to ease perception through the model. To achieve this; metaphors are utilized since they rely on references to the physical world. Even a pie chart or a tree chart carries a reference from our physical world being simple metaphoric depictions. The use of metaphor brings an understanding of relatively abstract information into a concrete visual form. Mary Lou Maher and Fei Li in their essay *Representing Virtual Places* emphasize how metaphor influences our ability to experience the cognitive unconscious in following statements:

> Appealing to the cognitive unconscious in the design of virtual worlds allows us to conceive of and develop a virtual world that can be used by people with a more "natural" response. Since we are born and learn to act in a physical world, much of our unconscious thinking is based on our learned responses to the physical world...much of our thinking is also based on conjunctions of physical experiences with subjective experiences. In designing and understanding virtual worlds, creating a place that is consistent with our understanding of the physical world will allow us to consistently apply the primary metaphors we used.[106]

In Asymptote's 3DTF VRE, the visualization aspects are based on the following activities all of which serve for a better comprehension and manipulation of financial data through a high degree of spatial organization for data visualization. The environment itself gives a feeling of being in a trading floor through the spatiality achieved in the model.

The plan of 3DTF VRE, which is called *activity map*, is available in the lower half of the main page and the 3D model is available in the upper half as seen in Figure 4.3. Besides them real time data on the stocks are being presented in the same page in a text form. Thus, it makes the user to feel the sense of control within the environment.

Figure 4.3 3DTF Main Page (source: Ibid.)

---

[106] Mary Lou Maher and Fei Li, 2000, *Representing Virtual Places - A Design Model for Metaphorical Design* [Internet, WWW,PDF].ADDRESS: http://www.arch.usyd.edu.au/~mary/Pubs/2000pdf/ACADIA2000.pdf [Accessed: 17 Dec 2004] p.9

In 3DTF model, over the walls, the main board displays NYSE logo. On the ground, sector figures are displayed over the dynamic virtual booths. What is critical with these booths is not the specific form of them; rather the fact that these forms are utilized to separately display financial data on each sector. On the other hand, it can easily be seen that there is a resemblance between the forms of virtual booths and the boots of the trade area in the actual NYSE. In this respect, this resemblance is a kind of symbolism, which enables the user to feel the sense of familiarity, which creates conjunctions of physical experiences through virtual environment.

Figure 4.4 (left) Actual Boots (source: NYSE Trading Floor, [Internet, WWW,] ADDRESS: http://www.rediff.com/news/2001/sep/18wtc4.htm [Accessed: 30 Dec 2004])

Figure 4.5 (right) Virtual Boots (source: NYSE Web Environment, [Internet, WWW,] ADDRESS: http://marketrac.nyse.com/mt/index.html [Accessed: 30 Dec 2004]

Over these booths there are panels showing stocks open for trade. Each booth has 20 official post numbers and composed of thirty panels. The colors in which a stock is indicated, refers to the direction of change: red referring to decline and green referring to the advance of the stocks being traded. This color system is called “flag.”

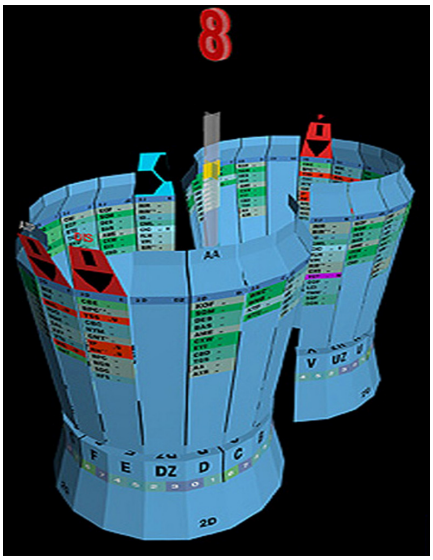

Figure 4.6 3DTF Virtual Boots (source: NYSE 3DTF, [Internet, WWW,] ADDRESS: http://www.asymptote.net [Accessed: 30 Dec 2004])

3D financial data architecture that works as real time graphics showing market parameters like prices of stocks, changes in the prices of stocks and trade volume, are represented under the 3D model of NYSE.

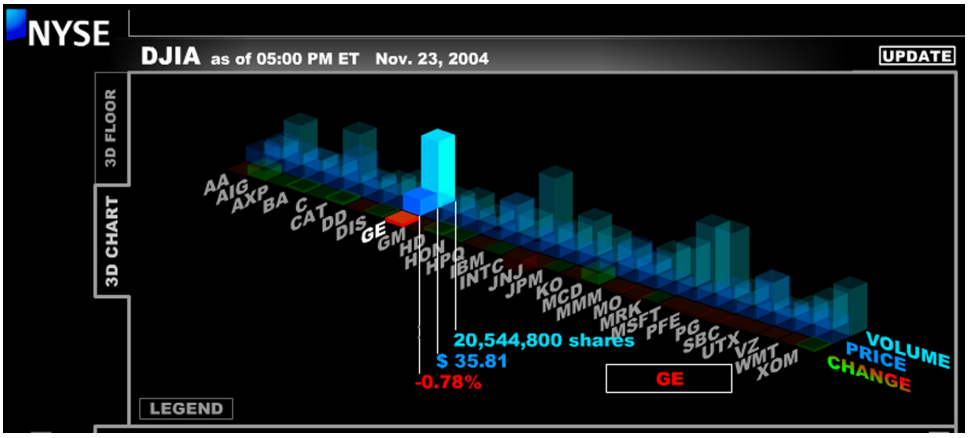

Figure 4.7 Interactive graphs inside the 3DTF (source: NYSE Web Environment, [Internet, WWW,] ADDRESS: http://marketrac.nyse.com/mt/index.html [Accessed: 30 Dec 2004]

The page also presents 3D graphics showing the declines and advances. These graphics give a feeling of being in spatial formation. For instance; when order flow link is clicked, the user is given two options to view *the composite index*; either a corridor formed 3D chart or a 2D frontal view graphic. Despite the data being identical in both options, the corridor formed in 3D chart presents the stock information in a much more easy way to perceive as shown in figure 4.8.

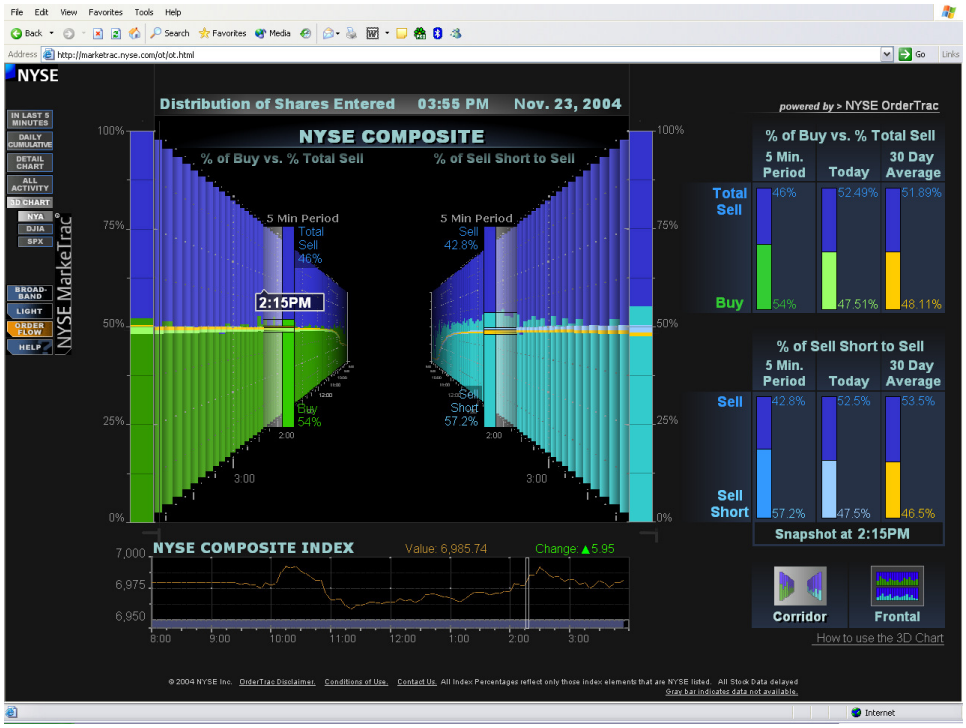

Figure 4.8 Corridor view of 3DTF Composite Index Graphic (source: NYSE Web Environment, [Internet, WWW,] ADDRESS: http://marketrac.nyse.com/ot/ot.html [Accessed: 30 Dec 2004]

The model enables a compact bird view, which is similar to feeling being in a stadium able to oversee all activities taking place.

In both situations, the perception of the facilities creates the feeling of being able to have a full picture of perception as if they are similar environments.

Figure 4.9 The views from 3DTF and a Stadium (source: photo by Galo Aguilar [Internet, WWW,] ADDRESS: www.davidnemeth.com/yankees.htm [Accessed: 30 Dec 2004]

All representations mentioned above are based on continuously changing real time information. Within the model, all types of digital media; text, images, 3D modeling, and animations, are available. As it is mentioned in the previous chapter, utilizing architectural and abstract metaphors ease the user perception in the model. With this respect, 3D information visualization improves the presentation and perception of large amounts of financial data.

In the future, it is planned that over side walls, live TV broadcasts (for instance CNN live) as well as broadcasts from actual NYSE will be visualized in video format. Over the same walls will be ticker bands showing market situation through the prices of shares etc., in conventional running text format. Economic real time events will also be displayed in text format on a sequential basis.

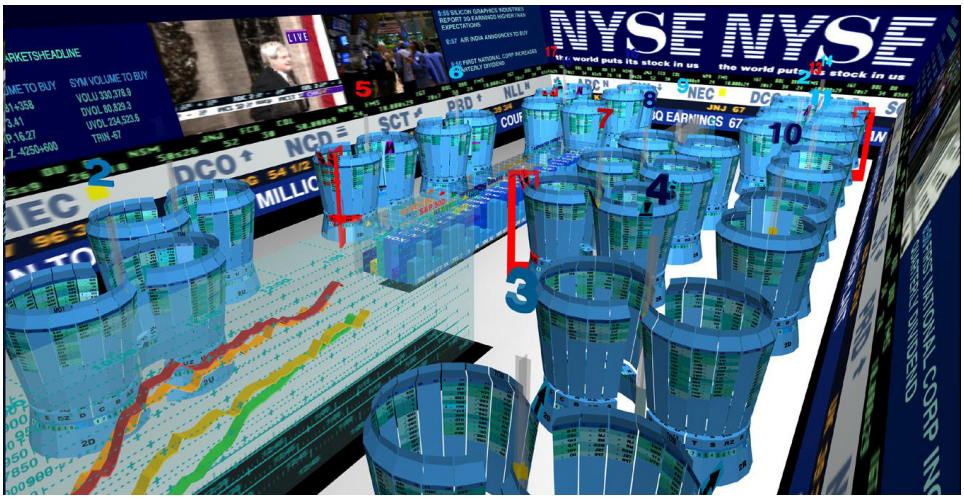

Figure 4.10 Future 3DTF Environment: TV Broadcasts, Ticker bands over the Side Walls (source: NYSE 3DTF, [Internet, WWW,] ADDRESS: http://www.asymptote.net [Accessed: 30 Dec 2004])

4.3.2 Navigation

Another important aspect is navigation through a realm of data. The navigation of data, for Asymptote, could be solved by combining information with a digital terrain or landscape using the tools of "composition, form (tectonics), and movement."[107] Due to massive amounts of data being processed; there was a need for way finding by graphical representations, which are processed simultaneously with the changing real time data. "[…] Data in the form of trade stocks experience an architectural mutation instead of conventional graphical display. The fully navigable artificial landscape reacts to all changes of stocks in real-time and its alarm will go off at certain pre-set

[107] Hani Rashid and Lise Anne Couture, 2002, *Asymptote: Flux* (London: Phaidon,) p. 35.

constellations."[108]

Moreover, the re-interpretation and transformation of the existing physical-actual trading environment is a basic key in the design of the 3DTF. According to Asymptote:

> …This was accomplished by developing a wire frame model that corresponded to the layout of the "real" trading floor and its constituent elements, their relative placement and geographic location on the floor. The architectural idealization had to provide absolute flexibility; particularly to accommodate the data feeds that would eventually be programmed into it. The modeling also needed to provide for constant shifts in scale, enhanced levels of detail, and the insertion of numerous other kinetic virtual objects. Thus the actual trading floor had to be reconfigured for several reasons: the model had to function in real time, which produced high technological demands; and an economy of form was necessary to process and animate extremely large quantities of data.[109]

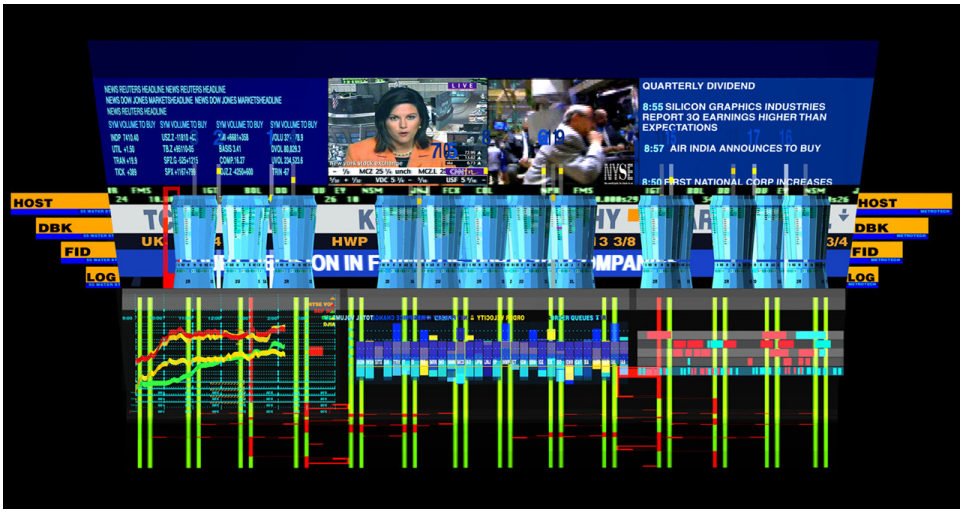

Figure 4.11 Connection between Economic Events and Media Reports of Cause-and-Effect (source: Ibid.)

Navigation in 3DTF model is designed so as to allow the model to move and rotate in all directions. 360 degree rotation, zoom in and out, and motion via hand tool are

[108] Hani Rashid, 1999, "NYSE DigitalReal," [Internet, WWW,] ADDRESS: http://www.a-matter.de/digital-real/eng/main.asp?pr=4 [Accessed: 20 Aug 2004]

[109] Hani Rashid and Lise Anne Couture, 2002, *Asymptote: Flux* (London: Phaidon,) p. 36.

possible through link or mouse clicks. Furthermore, reaching to booths is being enabled via flying animation. When a booth is clicked, reaching to that particular booth by flying animation is possible. For detailed stock information, the model requires double clicks on the panels and then on the symbols for details as well as for returning to panel list. Just by moving the mouse on the 3D activity chart, the presentation of all the past and recent trades of that stock is available.

Figure 4.12 Individual Stock Data in a Transparent View (source: NYSE Web Environment, [Internet, WWW,] ADDRESS: http://marketrac.nyse.com/mt/index.html [Accessed: 30 Dec 2004]

4.3.3 Interaction

The model allows the users to dynamically work with the financial data feeds over constant shifts in scale, enhanced levels of detail and dynamic virtual object displays.

Easy data access supports better understanding of the ongoing financial situation and improves client understanding.

The fact that users can navigate in the model to check the stock news, valuations and make trades constitutes the major interactivity in the model. The crucial point of interaction is the effect of user to change the total environment. In NYSE model, the user interacts with the architectural and abstract metaphors by using the information for his/her interests and changes the ongoing data accordingly. This situation creates dynamism in the environment and other users' perception.

4.3.4 Data Integration

The organization of financial data in NYSE VRE enables users to reach the financial flux of exchange. In addition in the future there will be media news reporting of cause and effect of the financial flux, which enables user to have opportunity for an objective point of view. By this way, in 3DTF model data integration, not only all text based or graphical representations of real time data will be integrated to each other, but also and more importantly "relationship between financial events and media news reporting of cause and effect is made transparent." [110]

Via data integration in NYSE VRE where data has utmost importance, 3D floor, 3D chart, activity map are all changing in consistency with each other based on continuously changing real time information and accordingly user interaction. However, all stock data being presented with 20 minutes delay.

On the basis of inspirations from Bermudez analysis of *Data Representation Architecture*[111] and above-mentioned framework of analysis, it is seen that in Asymptote's data visualization, design and representation process they;

1. refrain from creating a virtual building, a replica of the real one.

2. design the perceptive and functional qualities of space and form.

---

[110] Rashid, et.al., *Asymptote: Flux*, p. 36

[111] Julio Bermudez, Jim Agutter and Dwayne Westenskow, 2000, "Data Representation Architecture: Visualization Design Methods, Theory and Technology Applied to Anesthesiology." *ACADIA 2000.* [Internet, WWW,] ADDRESS: http://www.arch.utah.edu/people/faculty/julio/acadia2000.pdf [Accessed: 20 Aug 2004]

3. take advantage of the flexibility offered by cyberspace where visualization, navigation, interaction, and data integration are possible.

4. map information into a 3D data representation architecture in order to improve recognition while supporting data integration and significant increases in the number of variables to be displayed. All information and the daily trade activity and transactions are mapped into fully navigable, multi-dimensional environment. They linked the graphics and their financial meanings. This enables translation and understanding between numerical parameters and images or shapes. Real-time data is integrated to create a visual display that uses 3 dimension, animation, colors and geometric shapes to identify business and systems events.

6. integrate data in the model in a way to reveal data's relationships and interactions through representations. One to one coherence with NYSE real time information was also achieved

7. facilitate user's access to the information and enabled response from the model via interaction built into the model.

8. achieve formal, functional and technical simplicity.

4.4 Evaluation

Rashid refers to their understanding of digital architecture as "a new architecture of liquidity, flux and mutability, predicated on technological advances and fueled by a basic human desire to probe the unknown."[112] In 3DTF VRE, Asymptote utilized cyberspace, being an information space where data is configured based on users control, movement and access. Rashid and Couture define this environment, as a "multi-dimensional [direction, time, information] interactive data environment."[113]

[112] Hani Rashid and Lise Anne Couture, 2002, *Asymptote: Flux* (London: Phaidon), p. 69.

[113] Ibid., p.50.

Martin Dodge and Rob Kitchin in their book *Mapping Cyberspace* inform what 3DTF is capable of offerring. They refer to 3DTF as:

> A more photo-realistic, or literal, information landscape… In 3DTF information flows and real-time data are spatialized in a three-dimensional virtual environment… The information environment is used as a real-time decision support system for operators who manage the stock exchange, keeping vital networks and computer systems running as well as monitoring the actual information flows of the market performance… Users can be immersed in the interactive environment. Various real-time data streams on the business systems, including stock performance of individual companies and user-defined aggregations, the underlying networks and computer servers, and news broadcasts can be spatialized...[114]

In view of their approach to virtual architecture, Rashid and Couture put an emphasis on functionality. They state that:

> The Virtual NYSE is not a rendition or re-presentation of the existing facilities: Such a version would have entailed a model with marbled textures on the walls and perhaps even avatars strolling about the floor. That kind of representation ultimately is of little value in a data-driven information environment. The three-dimensional trading floor supplements the main trading floor, allowing users to enter a parallel reality and exist in an entirely different place.[115]

Asymptote's design for 3DTF digital environment is beyond a representation of NYSE, rather presents an expanded and enhanced environment that comprehends changing demands of data organization.

Referring to the capabilities of computer technology, Asymptote states "Even if we think of the computer as a neutral tool embedded into the complex procedures of design, it is still capable of dismantling our conventional modes of making, reading, writing, communicating, and inevitably comprehending."[116] As it is seen in 3DTF VRE, Asymptote has utilized these capabilities of the computers in order to achieve their aim. Through the application of digital architecture in 3DTF VRE, the significance of the integration of information and virtual environment comes into scene. Rashid states:

---

[114] Martin Dodge and Rob Kitchin, 2001, *Mapping Cyberspace*, (NY; London: Routlege,) p. 124.

[115] Hani Rashid and Lise Anne Couture, 2002, *Asymptote: Flux* (London: Phaidon,) p. 50.

[116] Asymptote, 1998, "The Difference-Scape," in John Beckmann, ed., The Virtual Dimension, (New York: Princeton Architectural Press,) pp. 287-291 quote p.287.

> All of the information that is relevant to the NYSE and its daily activity of trades and transactions is mapped into this *fully navigable multi-dimensional world*. Although the virtual-reality environment was initially designed to enable the NYSE to supervise their trading environment, the project has recently evolved to cater to other uses, including a large-scale internet initiative and a television broadcasting environment.[117]

Asymptote's VR environment as an extension of the real NYSE poses new architectural possibilities and experiences. One of them is the integration of the real and virtual information environments. Rashid referring to the evolution of the project to serve to other uses, states:

> These mutations and elaborations of the project have further architectural implications as the virtual realm slowly usurps the real trading floor as a "place." The fact, that the general public will soon be able to navigate a virtual trading floor, check stock news and valuations, make trades and meander about at will, is unprecedented and begs the question, What actually constitutes an architectural experience and presence? And for those who do inhabit and are familiar with the real trading floor, what new insights into their environment can be attained and how might these alter their understanding of what constitutes architecture?[118]

The re-interpretation of trading floor presents a provocation, because it provides an expanded and enhanced system for NYSE and triggers a change in expectations about future trading environments. For Rashid:

> The project posed an interesting opportunity to reconsider the "reality" of the actual trading floor: Asymptote's 3DTF version of the trading floor, although virtual and not intended to be constructed outside of a computer environment, is effectively a direction for possible future trading environments. The virtual trading floor as designed is both a reflection of the existing environment and a provocation for a new, physically augmented architecture.[119]

To conclude; Asymptote's NYSE VRE illustrates that through architectural design of computer generated environments, vast and increasing amounts of real time information can be dealt with. This environment serves as an extension to the physical NYSE environment by facilitating the reading, correlation and navigation of massive

---

[117] Hani Rashid and Lise Anne Couture, 2002, *Asymptote: Flux* (London: Phaidon,) p. 37 [emphasis mine]

[118] Ibid.

[119] Ibid., pp. 36-37.

amounts of information. This is managed through a design enabling three-dimensional visualization, navigation, and interaction through a realm of data processing and presenting these extremely large quantities of data. The model allows for instant replays of events, compression or overlapping data enabling the users to establish interpretations or relational thinking. These options are not available in real NYSE. In this sense virtual NYSE is a terrain where major material is information. This terrain extends the existence of real NYSE into the virtual domain offering new possibilities through a new perspective of design in and for this medium, which we call digital architecture. In other words it is an illustrating project for practice of digital architecture where its product, the VRE, serve as an extension of its real counterpart actual NYSE. Through this project, Asymptote not only creates an information space being in flux, liquid, dynamic, navigable and interactive but also a new metamorphic architecture reshaped by the information. For the thesis, this project is a pioneer for the future architectural practice, which will take place both in real and virtual environments.

CHAPTER 5

CONCLUSION

The thesis has argued that virtual reality environments serve as extensions of physical spaces, enriching and supporting them. Through the analysis of the particular case, Asymptote's NYSE VRE project, the thesis puts an understanding of how the architecture of and for information is created in digital environments. Via the environments designed by a new architecture built in and for the digital medium, which is called digital architecture, reading, correlating and navigating through massive amounts of information is eased.

Cyberspace and virtual reality have been discussed since they are the most significant concepts making digital architecture possible. The research on cyberspace and VR has affected and changed the agenda of architecture. Besides the three dimensions in which architecture takes place, a new dimension, 'virtual dimension,' has emerged.

Bermudez referred to the need for designing virtual environments by the following statement:

> Since people daily work, meet other people, seek entertainment, find-generate-store-communicate information, and sell-purchase goods and services within cyberspace, one would expect that this environment, like its physical sibling, requires planning, design, construction and continuous updates. Architecture, whose historical role has been to deal with such matters, is the appropriate discipline to address these very real needs of the virtual. The fact that the resulting constructions and environments are made of information and not of matter is ultimately irrelevant.[120]

[120] Julio Bermudez, 1997, "Cyber(inter)sections," Proceedings of the Symposium on Architectural Design Education: Intersecting Perspectives, Identities and Approaches. Minneapolis, MN: College of Architecture & Landscape Architecture, pp.57-63, [Internet, WWW], ADDRESS: http://www.arch.utah.edu/people/faculty/julio/isection.htm [Accessed: 20 Aug 2004]

This new dimension; virtual dimension can be described as transformed version of architecture when medium, context and process of design are considered. This medium in which it takes place is a realm free of physical world constraints, having a nature inhabiting algorithmic and relational thinking, where animation, simulation, modeling and the like are possible. Through digital architecture, what is being designed is the algorithms or relations that produces the environment rather the static object. As it is mentioned before, Novak explains the fact that, in digital architecture architects do not design the object but the software, the system which the object is being created. [121]

To clarify the idea of extension and the realization of this transformed architecture, Asymptote's NYSE VRE is a significant project, which searches for re-interpretation and transformation of space in digital environment, leading to a new kind of architectural experience. The project aimed to eliminate the difficulty in reviewing, processing, storing, etc. vast amounts of information and managed to create an NYSE VRE which is an extended digital information space augmenting the real NYSE.

In a broad sense, the impacts of technology on the life of human beings are enormous. With the rise of digital and communication technologies through the introduction of virtual dimension, further changes in all aspects of our lives become only a matter of time. I believe that the coexistence of real and virtual as referred by Mitchell "schoolhouses and virtual campuses; hospitals and telemedicine, trading floors and electronic trading systems, bookstores and bit stores"[122] and the like indicates that virtual dimensions will not only have an increasing share in all areas of life but also change our expectations about future life.

Within the same respect in particular, with digital technologies, the importance of multi-dimensional information environments has not posed a challenge to physical spaces but brought up an increased significance of cyberspace in our lives.

---

[121] Marcos Novak, "Liquid Architectures in Cyberspace," in Michael Benedikt, ed., 1991, *Cyberspace: First Steps*, (Cambridge: The MIT Press,) p. 251.

[122] William J. Mitchell, 1995, *City of Bits: Space, Place, and the Infobahn.* (Cambridge, Mass.: MIT Press,) pp.46-105.

William Mitchell refers to the future prospects in all areas of life including architecture by stating that:

> Architects of the twenty-first century will still shape, arrange, and connect spaces (both real and virtual) to satisfy human needs. They will still care about the qualities of visual and ambient environments. They will still seek commodity, firmness, and delight. But commodity will be as much a matter of software functions and interface design as it is of floor plans and construction materials. Firmness will entail not only the physical integrity of structural systems, but also the logical integrity of computer systems. And delight? Delight will have unimagined new dimensions. In a world of ubiquitous computation and tele-communication, electronically augmented bodies, postinfobahn architecture, and big-time bit business, the very idea of a city is challenged and must eventually be reconceived. Computer networks become as fundamental to urban life as street systems... Much of the economic, social, political and cultural action shifts into cyberspace. As a result, familiar urban design issues are up for radical reformulation.[123]

Digital developments are taking place too fast to follow. As stated by Emre Kongar in his essay *Yeni Bir Çağın Eşiğinde Değil, İçindeyiz* (*We are not at the edge of a New Era, Rather in It)*, "the new era is defined by communication-informatics revolution. Humanity experiences communication-informatics revolution as the third biggest revolution following agriculture and industrial revolutions."[124] These developments will have very strong impacts at least as much as the impacts of the past industrial revolution.

Based on continuous developments in communication and digital technologies, in near future, I believe that a new architectural discipline –cyber or digital architecture- will emerge.

---

[123] Ibid., pp.105-107.

[124] Emre Kongar, 2001, Yeni Bir Çağın Eşiğinde Değil, İçindeyiz, [Internet, WWW], ADDRESS: http://www.kongar.org/aydinlanma/2001/293_Yeni_Bir_Cagin_Icindeyiz.php [Accessed: 22 Nov 2004] A copy of this article is in the author's possession and may be consulted by contacting the author at emre@kongar.org <emre@kongar.org>

APPENDIX A

CONCEPTUAL RELATIONS OF THE FRAMEWORK

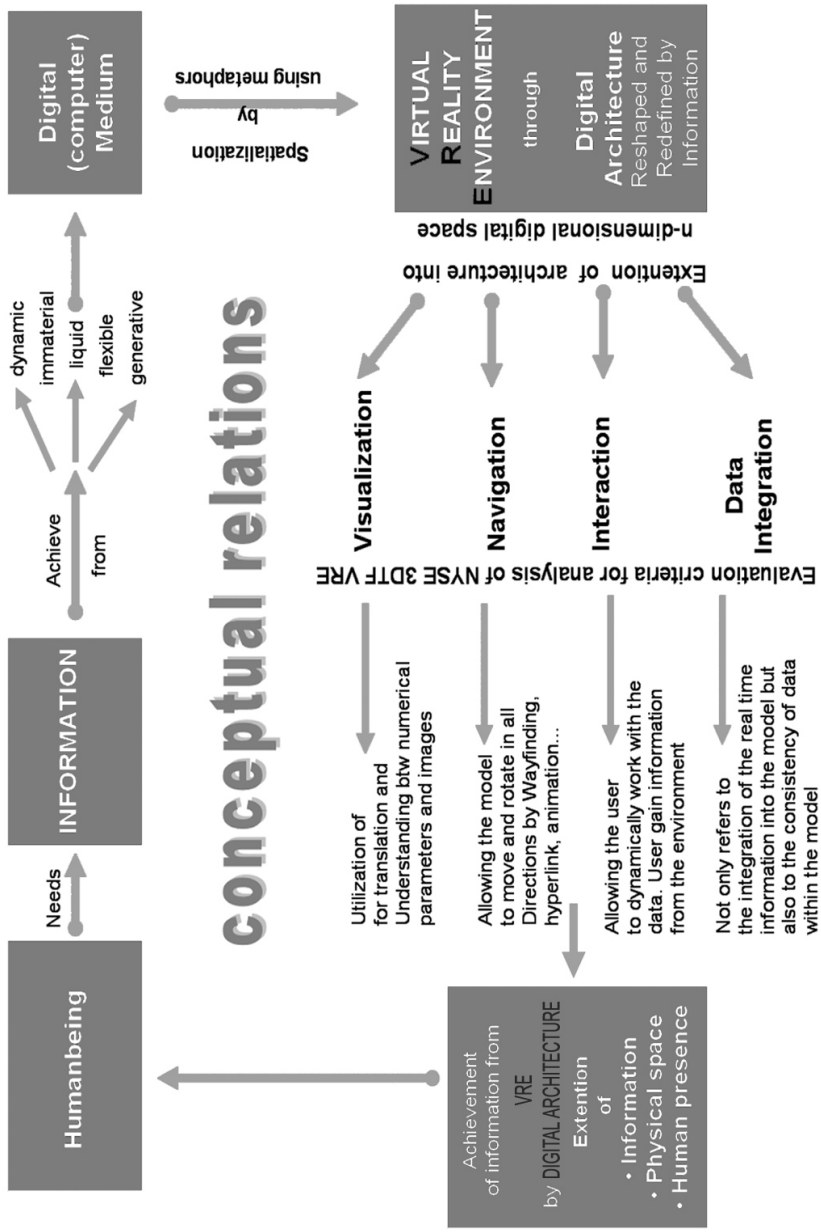

Figure A.1 Conceptual Relations of the Framework

APPENDIX B

NYSE 3DTF VRE FACTS

Project Leaders/Managers:

NYSE:

· Anne Allen, Senior Vice President, Floor Operations and Mark Hicks, Manager, Floor Operations were responsible for the concept and development of the 3DTF and advanced Trading Floor Operations Center. Ms. Allen and Mr. Hicks will continue to provide ongoing leadership and management of the new technology and workspace.

· Contact: Catherine Parker/NYSE (212) 656-5437

Securities Industry Automation Corporation (SIAC):

· Dror Segal, Senior Director of New Technologies at SIAC, served as the systems, architect and technical project manager. SIAC took the lead in creating and developing the real-time 3-D Trading Floor model and software application.

· SIAC provides automated information and communications systems that support the business activities of the New York and American Stock Exchanges, the National Securities Clearing Corporation and the securities industry nationwide. SIAC is a subsidiary of the New York and American Stock Exchanges.

· Contact: Dror Segal/SIAC (212) 383-3431, Phyllis Rieger/ SIAC (212) 383-3733.

Vendors:

Asymptote Architecture:

· Asymptote Architecture designed and provided external management for the computer-generated architectural environment and the advanced Trading Floor Operations Center.

· Asymptote Architecture is a New York-based architectural practice specializing in both building design and virtual reality environments. The practice was established in 1989 as collaboration between architects Lise Anne Couture and Hani Rashid.

· Contact: Lise Anne Couture/Asymptote Architecture (212) 343-7333.

RT-SET:

· RT-Set wrote the animation code for the 3DTF virtual environment.

· RT-SET (Real Time Synthesized Entertainment Technology), a developer and marketer of fully integrated, 3-D computerized broadcasting systems, was established in early 1994 by BVR Technologies, a world leader in the development of highly sophisticated simulation and training systems. The company is based in Shefayim, Israel.

· Contact: Isaac Schwarzenberg/RT-Set 011-972-9-9552236 or isaac@rtset.co.il

Silicon Graphics:

· The 3DTF operating system is based on four Silicon Graphics Onyx2 visualization supercomputers (two additional Onyx2 computers are used for offsite support). The 3DTF also uses the high-end Silicon Graphics Iris Performer as a software foundation.

· Silicon Graphics is a leading supplier of visual computing and high-performance systems. The company's shares are listed on the NYSE under the ticker symbol SGI.

· Contact: Kevin Burr/Silicon Graphics (650) 933-5411

PixelVision:

· PixelVision supplied the complete information display solution. The company's SmartGlas technology was employed extensively to handle the project's requirements. High resolution, 18-inch diagonal flat-panel monitors, some enabled with touch input capability, were used for the video wall. 25-inch diagonal flat panel monitors were adapted as the basic building block for the unique 3-D display wall.

· The Trading Floor Operations Center is equipped with 43 PixelVision flat-panel monitors:

- 3DTF: Nine 25-inch flat-panel monitors
- Operations Center Display Wall: Thirty-four 18-inch flat-panel monitors

· PixelVision is a leading worldwide supplier of flat-panel solutions used in information-intensive, space limited environments with mission-critical display needs.

· Contact: Donna Hubbard/PixelVision (978) 264-9443

Milgo/Bufkin

· Milgo/Bufkin supplied all of the architectural components of the Trading Floor Operations Center: the blue glass monitor wall, contoured steel cabinets, graphic wall, metal clad walls, curved railing at the edge of the platform, broker booth partitions, metal ceiling with light cannon and cantilevered ceiling extension that leads to the main trading room.

· Milgo/Bufkin is a custom fabricator of architectural metal, combining high technology with old-world craftsmanship, to transform stainless steel, aluminum, bronze, titanium and other metals in a wide variety of finishes, into objects of beauty and utility.

· Contact: John Lobel /Milgo/Bufkin (212) 679-1935

Morse Diesel International, Inc.

· Morse Diesel served as construction manager, coordinating the efforts of the architect and various subcontracters to renovate the Trading Floor Operations Center workspace. All renovations were completed without disruption to the safety or operations of the trading floor activity.

· Morse Diesel is a large, national construction management firm that has been working at the New York Stock Exchange for more than twenty-five years.

· Contact: John Giammarella/Morse Diesel (212) 484-0300

APPENDIX C

NYSE CONTACT INFORMATION

A: Actual NYSE Contact Information

Visiting the NYSE: The NYSE is not currently open for visits or tours

Mailing Address: New York Stock Exchange, Inc.11 WallStreet New York, NY 10005

Phone: 001 212.656.3000

Figure C.1 NYSE Map (source: NYSE Web Environment, [Internet, WWW,] ADDRESS: http://www.nyse.com/about/theorganization/1095581297148.html [Accessed: 30 Dec 2004]

B: NYSE 3DTF VRE

http://marketrac.nyse.com/mt/indexFullIntro.html

GLOSSARY *

Algorithm: A more or less involved mathematical procedure that can be used repeatedly to produce predictable results. Mathematical algorithms are used when RENDERING a final image from a wire frame model. (Weishar, 1998, p.217)

Animation: Literally means "giving life or motion." It is the creation of simulated movement with inanimate objects. (Weishar, 1998, p.217)

Artificial Life: Computerized agents that simulate biological life-forms have artificial life, or a-life. Such agents reproduce, evolve, and carry out the dynamic processes of organic life. (Heim, 1993, p.148)

Artificial Reality: (AR) means an unencumbered involvement in a computerized environment. Computerized sensors "perceive human actions in terms of the body's relationship to a simulated world. The computer then generates sights, sounds, and other sensations that make the illusion of participating. Artificial reality belongs to VR in the sense that participants aesthetically enter a computer-enhanced environment, but AR systems do not require goggles or datagloves, and such systems involve full-body motion without wiring humans to an interface. (Heim, 1993, p.148)

Behavior: A control that can be attached to an object that simplifies the animation process. Usually behaviors are associated with simple movements such as "spin, bounce, and look at." (Weishar, 1998, p.218)

Click and Drag: To press the mouse button and hold it down while moving the mouse. This can be done to move and object within the view or to select an area or a group of objects. (Weishar, 1998, p.220)

---

* These definitions are taken from the books: Michael Heim, 1993, *The Metaphysics of Virtual Reality*; Peter Weishar, 1998, *Digital Space: Designing Virtual Environment*; and Gerhard Schmitt, 1999, *Information Architecture: Basis and Future of CADD.*

Cyber: A prefix found throughout the literature of VR. The root reference is to cybernetics, the science of self-regulating systems, but the reference has expanded to become a name for mainframe computers (the Cyber 960) and now connotes the human involvement with computers (the cyborg, or cybernetic organism). For instance, the primary human body becomes a cyberbody when appearing in the cyberspace of a virtual environment. (Heim, 1993, p.149)

Cyberglove: Another form of the dataglove, or device for monitoring hand movements so that the user's position and gestures can be calculated and the computer can adjust the graphic virtual environment accordingly. (Heim, 1993, p.150)

Cyberpunk: A postmodern literary-cultural style that projects a computerized future. The future is dominated by private corporations that use information technology and drugs to control individuals. Cyberpunk stories are told from the criminal perspective and portray the widespread use of biotechnology, computers, drugs, and a paranoid life-style. Individuals increasingly merge with electronic devices, and hallucinations rule public life. Cyberpunk is based on a dystopian brand of science fiction whose patron saint is Philip K. Dick and whose manifesto is William Gibson's novel Neuromancer. The term was coined by the science fiction writer Bruce Bepkie and became a literary critical term with Gardner Dozois, the editor of Isaac Asimov's Science Fiction Magazine. (Heim, 1993, p.150)

Cyberspace: In 3D graphics, the virtual space inside the computer where scenes are constructed; also called the WORLD. Cyberspace is also used to describe the intangible world of digital information that can be accessed through the internet. (Weishar, 1998, p.221)The juncture of digital information and human perception, the "matrix" of civilization where banks exchange money (credit) and information seekers navigate layers of data stored and represented in virtual space. Buildings in cyberspace may have more dimensions than physical buildings do, and cyberspace may reflect different laws of existence. It has been said that cyberspace is where you are when you are having a phone conversation or where your ATM money exists. (Heim, 1993, p.150)

Data: In the computer world, any information recorded, stored, manipulated or transmitted as binary digits. It may represent images, text, statistics or whatever**.** (Weishar, 1998, p. 222)

Data Base: Broadly, a program and an area of memory used to store and organize data. Special programs used to store data and access it quickly using specialized languages. Data bases are the key for the management of large data sets and are used in almost every company and recently by Web servers to make information available on the WWW. (Weishar, 1998, p. 222)

Dataglove, Cyberglove: A sensor-laced nylon glove that provides manual access to objects in virtual environments, sometimes also enabling a variety of gestures to initiate movements in the virtual world. That is, the glove has fiber-optic sensors to track hand and finger positions, permitting the user to reach out, grab, and change objects in the virtual world. Present-day data gloves register the hand positions and the degree of movement of each finger but do not yet register the somatics, the inward kinesthetic of movement that are more difficult to measure. (Heim, 1993, p.150)

Datasuit: A sensor-equipped garment like the dataglove but covering the whole body in order to track the user's movements and to provide constant input into the host computer so the computer-generated graphics environment and the cyberbody can be updated according to the user's gestures and orientation. (Heim, 1993, p.151)

Digital Realm: The data-based environment within a computer. (Weishar, 1998, p.223)

Human-Computer Interaction: HCI studies how to access computer power. The computer industry developed "human factors engineering" to explore different kinds of input ranging from binary code to alphanumeric keyboards to touchscreens and the mouse or track ball. Seen from the HCI viewpoint, VR is a latest development in "user friendlimess." The HGI approach, however, misses the broader implications of the human entrance into virtual reality. (Heim, 1993, p.153)

Internet: A global information network connecting approx. 20 million machines and 100 million users in 1998. The common denominator for all machinery connected to the internet is the low-level protocol ("language") TCP/IP. The internet uses phone lines, satellite links, special high-capacity wires and other connections to link the machines. (Schmitt, 1999, p.86)

Immersion: An important feature of VR systems. The virtual environment submerges the user in the sights and sounds and tactility specific to that environment. Immersion creates the sense of being present in a virtual world, a sense that goes beyond physical input and output How presence and Immersion coalesce remains an open question in VR research. (Heim, 1993, p.154)

Interface: The locus of communication between two systems, applied to either hardware or software or a combination of both. A graphical interface, for example, may use metaphors such as a desktop or house with garbage pail, paintbrush, or yardstick. An alphanumeric interface, such as that of an IBM-style personal computer, consists of a monitor and a keyboard and the appropriate software for input and output. Interface is a key term in the philosophy of technology because it designates the connecting point between human and digital machine. (Heim, 1993, p.155)

Metaphysics, Metaphysical: The study of the first principles of reality, including speculation on epistemology (knowledge), ontology (being), ethics (goodness), and aesthetics (beauty). The metaphysics of VR treats issues such as presence, degrees of reality, objectification (first person, third person), simulation versus reality, the ratio of mental to sensory material, the ethics of simulation, the evaluation of virtual environments, and the central coordination of virtual realities. Traditional metaphysics also treats topics such as possible worlds, intrinsic goals (teleology), and umbrella concepts like meaning and final purpose. (Heim, 1993, p.155)

Network, The Net, The Matrix: A network connecting computers through cables, telephone lines, or satellite transmission. The global Internet network connects institutions of all kinds: military and government, commercial and educational.

Networks also exist in local areas such as a business and on commercial mainframe computers, such as those used by CompuServe and Prodigy. Most often, gateways exist through which one network opens onto another. (Heim, 1993, p.156)

Presence: A notion crucial to early-twentieth-century philosophy. In Heidegger's Being and Time (1927), presence is synonymous with being and is a function of temporality. The entire history of reality, according to Heidegger, must be reconsidered from the standpoint of presence. Presence is also a key term in VR, with researchers seeking to define and quantify the presence that a given system will deliver. (Heim, 1993, p.157)

Real Time: On a computer that's powerful enough, input data and graphics can be process in real time- as the work is going on, or as the game is being play- so that any changes result in near-instantaneous adjustments to the image. (Weishar, 1998, p.234)

Rendering: The process in which the computer combines all the specified object and light data to create an image either a still or a frame in an animation. (Weishar, 1998, p.235)

Software: The programs and data that make a computer work. (Weishar, 1998, p.236)

Three-Dimensional (3D): Relating to objects that have the three dimensions of height width and depth. Computer generated 3D objects can be freely manipulated in computer space. (Weishar, 1998, p.238)

Trackers: Position-tracking devices that constantly monitor the user's physical body motions—hand, head, or eye movements—so as to feed the user's actions into the host computer, in which motions are interpreted as changes in the computer-generated environment. Some of the earliest devices for tracking head position, and hence visual perspective, are the 3Space Isotrak by Polhemus, Inc., and the Bird by Ascension Technology. Position-tracking devices by themselves do not register the user's somatic states. (Heim, 1993, p.159)

Virtual: A philosophical term meaning "not actually, but just as if." It came into recent vogue with the use of computer techniques to enhance a computer memory. Virtual-memory techniques extend the data storage of a computer without adding hardware. On a personal computer,' for example, virtual memory can be a part of RAM used as though it were a hard disk storage space. Such a virtual disk can be used like a hard disk, but does not have the physical limitations of an actual mechanical disk. Similarly, something can be present in virtual reality without its usual physical limitations. The debate about the value of virtual existence has appeared throughout the history of philosophy, with an especially vigorous debate in the era of Duns Scotus at the end of the medieval period and the beginning of the age of nominalism. (Heim, 1993, p.160)

Virtual Reality (VR): Any of various forms of computer-generated 3D environments, the more interactive and immersive the better. (Weishar, 1998, p.241)Virtual reality pertains to convincing the participant that he or she is actually in another place, by substituting the normal sensory input received by the participant with information produced by a computer. This is usually done through three-dimensional graphics and input-output devices that closely resemble the participant's normal interface with the physical world. (Heim, 1993, p.160)

Virtual World, Virtual Environment: A scene or an experience with which a participant can interact by using computer-controlled input-output devices. Most virtual worlds attempt to resemble physical reality, but controversy continues about the value of various levels of resemblance. Virtual worlds are not tied to physical reality, since any information that can be visualized can also be made into a virtual world that a participant can experience. Cyberspace, in other words, contains many kinds of virtual worlds. Even if a virtual world imitates a physical world, a decision has to be made whether the VR should imitate the perceived world of human phenomena or the world known to physical sciences (which often defies the assumptions of human phenomenology). (Heim, 1993, pp.160-161)

Wire frame: A method used to render or display geometry that draws objects using lines to represent the polygon or spline edges. (Weishar, 1998, p.241)

BIBLIOGRAPHY

Anders, Peter. 1999. *Envisioning Cyberspace*. NY: McGraw-Hill.

Baehring, Sebastian. 2000. "Design Studio: Introduction to the Design Studio [digital_space]: Solid and Virtual Architecture." Bauhaus - University of Weimar. [Internet, WWW]. ADDRESS: http://infar.architektur.uni-weimar.de/infar/engl/teachings/archive/design_studios/digital_space/ss01/lectures/000/print.html [Accessed: 20 Aug 2004].

Beckmann, J. ed. 2001. *The Virtual Dimension*. New York: Princeton Architectural Press.

Benedikt, Michael. ed. 1991. *Cyberspace: First Steps*. Cambridge: The MIT Press

Bermudez, Julio. "Architectural Visions: Non-Verbal Essays on Cyberspace." Work presented at the 4th CyberConf. The Banff Centre for the Arts, Banff, Canada, 1994 *Collected Abstracts of the Fourth International Conference on Cyberspace.* (The Banff Centre for the Arts, Banff, Canada,) p. 19. [Internet, WWW,] ADDRESS: http://www.arch.utah.edu/people/faculty/julio/visions.htm [Accessed: 20 Aug 2004]

Bermudez, Julio and K. King. 1995. "Architecture in Digital Space: Actual & Potential Markets." Kalisperis & Kolarevic (eds.). *ACADIA 1995* (Seattle, WA: University of Washington), pp. 405-423 [Internet, WWW]. ADDRESS: http://www.arch.utah.edu/people/faculty/julio/cyber2.htm [Accessed: 20 Aug 2004]

Bermudez, Julio 1997. "Cyber(inter)sections." Proceedings of the Symposium on Architectural Design Education: Intersecting Perspectives, Identities and Approaches. Minneapolis, MN: College of Architecture & Landscape Architecture, pp.57-63, [Internet, WWW] ADDRESS: http://www.arch.utah.edu/people/faculty/julio/isection.htm [Accessed: 20 Aug 2004]

Bermudez, Julio, Jim Agutter and Dwayne Westenskow. 2000. "Data Representation Architecture: Visualization Design Methods, Theory and Technology Applied to Anesthesiology." *ACADIA 2000.* [Internet, WWW,] ADDRESS: http://www.arch.utah.edu/people/faculty/julio/acadia2000.pdf [Accessed: 20 Aug 2004]

Bertol, Daniela. 1996. *Designing Digital Space: An Architect's Guide to Virtual Reality.* New York: J. Wiley.

Bridges, A. and D. Charitos. 1997. "On architectural design in virtual environments." *Design Studies* 18, p.143

Curtis, Pavel. 1992. *Mudding: Social Phenomena in Text-Based Virtual Realities.* Submission to the 1992 Conference on Directions and Implications of Advanced Computing, [Internet, WWW]. ADDRESS: ftp://parcftp.xerox.com/pub/MOO/papers/DIAC92.txt [Accessed: 17 Dec 2004]

Dodge, Martin and Rob Kitchin. 2001. *Mapping Cyberspace*. NY; London: Routlege.

Encarta® World English Dictionary ©. 1999. Microsoft Corporation, All rights reserved. Developed for Microsoft by Bloomsbury Publishing Plc. [CD-Rom]

Featherstone, Mike and Roger Burrows. eds. 1995. *Cyberspace/Cyberbodies/Cyberpunk: Cultures of Technological Embodiment.* London: SAGE.

Gliemann, Claudia. "Urban Drift." A*rchis.* 1999, nr: 10. pp. 77-80. [Internet, WWW]. ADDRESS: http://www.urbandrift.org/press/press_05.html [Accessed: 20 Aug 2004]

Griscon, Amanda. Aug. 2003. "Trends of Anarchy and Hierarchy: Comparing the Cultural Repercussions of Print and Digital Media." [Internet, WWW,] ADDRESS: http://www.cyberartsweb.org/cpace/infotech/asg/ag8.html [Accessed: 20 Aug 2004]

Gullbring, Leo A. 2001. "Marcos Novak." [Internet, WWW,] ADDRESS: http://home.swipnet.se/~w-35482/novak2.htm [Accessed: 20 Aug 2004]

Heim, Michael. 1993. *The Metaphysics of Virtual Reality.* New York: Oxford University Press.

Ito, Toyo. Mar 2000. "Image of Architecture in Electronic Age." [Internet, WWW,] ADDRESS: http://www.um.u-tokyo.ac.jp/dm2k-umdb/publish_db/books/va/english/virtual/01.html [Accessed: 20 Aug 2004]

Kitchin, Rob. 1998. *Cyberspace: The World in the Wires.* Chichester; New York: J. Wiley & Sons.

Maher, Mary Lou and Ning Gu, 2004, *Virtual Architecture*, [Internet, WWW,PPT].ADDRESS:www.arch.usyd.edu.au/~mary/DESC9103/va_intro.ppt [Accessed: 17 Dec 2004] p.29

Maher, M. L., Ning Gu and Fei Li. 2001."Visualisation and Object Design in Virtual Architecture" quoted in J. S. Gero, S. Chase and M. Rosenman (eds), *CAADRIA2001*, Key Centre of Design Computing and Cognition, University of Sydney, pp. 39-50. [Internet, WWW,PDF]. ADDRESS: http://www.arch.usyd.edu.au/~chris_a/MaherPubs/2001pdf/CAADRIA01.pdf [Accessed: 17 Dec 2004]

Maher, M. L., and Fei Li, 2000, *Representing Virtual Places - A Design Model for Metaphorical Design* [Internet, WWW,PDF].ADDRESS: http://www.arch.usyd.edu.au/~mary/Pubs/2000pdf/ACADIA2000.pdf [Accessed: 17 Dec 2004]

Maher, M. L., B. Skow and A. Cicognani. 1999. "Designing the virtual campus." *Design Studies* 20(4). p.322.

McLuhan, Marshall. 1987. *Understanding media :the extensions of man*. London: Ark.

Microsoft Press® Computer and Internet Dictionary ©, 1997, 1998, 1999, Microsoft Corporation, All rights reserved. [CD-Rom]

Mitchell, William J. 1995. *City of Bits: Space, Place, and the Infobahn.* Cambridge, Mass.: MIT Press.

Packer, Randall and Ken Jordan, 2002, *Multimedia; From Wagner to Virtual Reality*,W.W, (Norton, New York) [Internet, WWW,] ADDRESS: http://www.artmuseum.net/w2vr/timeline/Novak.html [Accessed: 20 Aug 2004]

Rashid, Hani. 1999. "NYSE: DigitalReal." [Internet, WWW,] ADDRESS: http://www.a-matter.de/digital-real/eng/main.asp?pr=4 [Accessed: 20 Aug 2004]

Rashid, H. and L. Anne Couture. 2002. *Asymptote: Flux.* London: Phaidon.

Schmitt, Gerhard. 1999. *Information Architecture: Basis and Future of CADD.* Trans. Lucinda Byatt. Basel; Boston; Berlin: Birkhauser.

Tappedin. [Internet, WWW] ADDRESS: http://www.tappedin.org [Accessed: 17 Dec 2004]

The Virtual Campus. [Internet, WWW] ADDRESS: http://www.arch.usyd.edu [Accessed: 17 Dec 2004]

Trace City. [Internet, WWW] ADDRESS: http://caad.arch.ethz.ch/trace [Accessed: 17 Dec 2004]

Turkle, Sherry. 1995. *Life on the Screen*. NY: Simon & Schuster.

Weishar, Peter. 1998. *Digital Space: Designing Virtual Environments*. New York: McGraw-Hill.

Zellner, Peter.1999. *Hybrid Space.* London: Thames & Hudson.