CITYCLUSTER
"FROM THE RENAISSANCE TO THE MEGABYTE NETWORKING AGE"
A VIRTUAL REALITY & HIGH SPEED NETWORKING PROJECT

Abstract

This paper presents CITYCLUSTER project, a virtual-reality networking matrix, a high-tech framework with original technological features, navigation and interactivity, graphic and content style, in which multiple environments, ambiences, and cities, both real and imagined, can be hosted, coexist and be interrelated within themselves through a common virtual territory. It can be interconnected by high-speed network, enabling remote participants to access, interact and collaborate in shared environments and work together in a common virtual space over distance in real-time. The framework can be expanded and modified in accordance with the digital environment to be incorporated. Meta-Net-Page, a virtual-reality collaborative networking tool, was designed and implemented ad hoc for CityCluster.

"From the Renaissance to the Megabyte Networking Age" is the first CITYCLUSTER virtual-reality networked application, which offers visitors a thrilling interactive journey, from the Renaissance to the Super Broadband Networking and electronic Age. Florence represents the "Renaissance Age", Chicago the "Gigabits Networking Age". Each virtual city is inhabited by a group of avatars: David, Venus, and Machiavelli in Florence, and Mega, Giga and Picasso in Chicago.

The implementation of CITYCLUSTER has given rise to a range of technological challenges, which in turn revealed innovative aspects and salient features relative to content management, the development of juxtaposed virtual environments, networking interactive techniques, avatar design, architecture, and virtual effects. A series of special features and enhancements have been added to the software Ygdrasil, to satisfy content and quality levels of interactivity. In consequence the Ygdrasil system was further refine as software tools that aid the rapid and intuitive development of interactive virtual environments for artists and other non-technical users.

CITYCLUSTER project is primarily designed to run in the CAVE® and on the AGAVE™ (Access Grid augmented Virtual Environment). It can run either locally or through remote networking in both SGI's and Linux platform.

Keywords

Tele-collaborative virtual reality, virtual reality, virtual reality authoring environments, context sensitive interface elements, remote collaboration, collaborative virtual environments, virtual reality networking matrix, distributed virtual environments.

INTRODUCTION

The CITYCLUSTER project provides new, spontaneous, and fluid virtual code for communication and interactive iconography of interactive networked pieces. It produces engaging virtual environments, creative networked terrains with tools, features, and facilities where visitors, regardless of cultural or professional identification, may feel free to express and intervene with their own creativity and communicative skills. The system has been designed to produce an integrated computing facility and to implement a high speed digital container in which multiple environments may coexist and be interconnected within a common, virtual territory.

This project seeks to explore new modes of collaboration, using the network as a common infrastructure, operating system and communication tool. Putting emphasis in the creative design and conception of the avatars and focusing on their character, personality and narrative through remote interactivity, allowing the exploration of a more artistic and intuitive approach for multi-linear participatory interactive experience.

The networked experience can take place in real-time between two diverse remote sites using virtual-reality networking platforms such us the CAVE® and the AGAVE™. Both platforms interconnect and run over high-speed networks, enabling local and remote visitors to navigate, interact, and communicate with each other through the avatars as well as with three-dimensional models over distance in real time, in a common virtual space. Passive and active stereoscopic glasses allow them to see in 3 dimensions. A simple tracked input device, "the wand," containing a joystick and 3 buttons, allows the visitor to navigate through the VR space, manipulate virtual objects and to interact with one another. High-speed network connectivity is required to support several simultaneous clients, given the amount of dynamic data in the environment and the streaming audio communication.

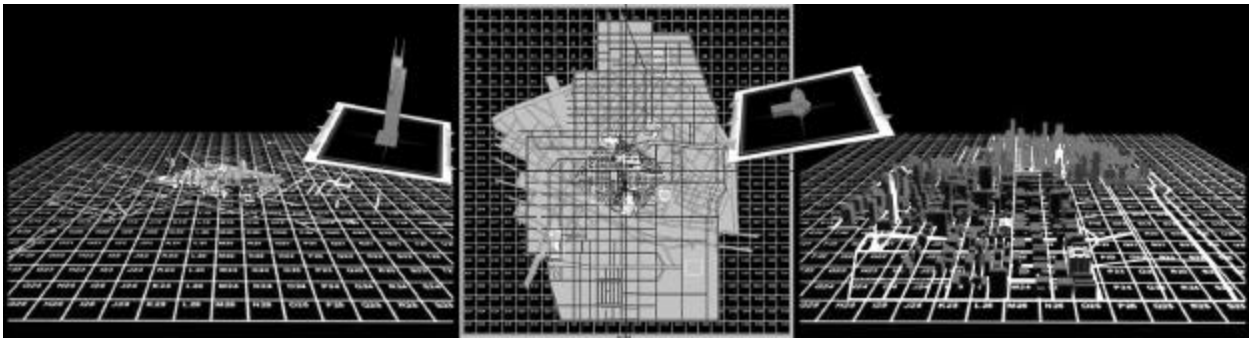

Figure.1. Florence and Chicago on CC-MATRIX

2. TECHNICAL & CREATIVE CHALLENGES

2.1 Tech implementation

The implementation of City Cluster presented diverse technical difficulties and challenges. Due to the fact that the author's concept and ideas surpassed the capacity and features of the YGdrasil system software employed throughout the project, thus calling for new solutions and technical implementations.

In order to facilitate the development of CITYCLUSTER project, effort was made to glean functionality from previously generated modules and distill it into its constituent parts. New module components incorporate spatialized sound, video clips, alternate perspective views and enhanced real-time texture manipulation. In addition, a large collection of general-purpose modules ranging from sensors that detect user position to tools that morph between multiple 3D models, were created for the CITYCLUSTER project. These new modules and the improvement of the current capabilities of the YG system will allow future users to take advantage of their functionality.

2.2 Core components of Ygdrasil

The core components of Ygdrasil are functions, such as navigation, terrain-following and sensor-based transformations, which are commonly found in virtual-reality applications. These functions, along with functions for transforming coordinate systems and loading three-dimensional models, are organized into components that can be arranged and interconnected through the use of a scripting language. This method of authoring has created a system that allows the rapid creation of simple virtual environments and allows components to be connected together to create new and unique interactive worlds. While the ability to create virtual worlds from a text script can be found in other software environments, such as VRML, the Ygdrasil system is unique in that tele-immersion, or collaborative virtual reality, is seamlessly build into the system. Artists creating virtual worlds with Ygdrasil can allow other users to join them in a tele-immersive world with almost no modification of their original content.

2.3 Improvement of the Ygdrasil system

The project calls for the ability to "capture" elements from one city and add them to the other city. This poses a challenge because what constitutes an "element" may not be easily added to another geographic location elegantly. The elements envisioned range from entire buildings to simple architectural components such as windows and door treatments.

In order to accommodate the capture of such a range of elements, it was necessary to employ a mixture of modeling techniques and programming processes. If architectural elements of buildings are modeled in a consistent manner, then the textures defining them can be exchanged to give predictable results. Entire buildings can easily be transposed from one environment to another if the possible geographic arrangement of buildings has been reconfigured.

The strategy adopted in view of project requirements foresees the user being able to exchange a limited selection of both architectural elements and entire buildings. Furthermore, the possibility of both permanent and temporary modifications to building textures was envisioned for the project.

A collection of components was added to the system that allows the real-time modification of textures associated with models. These modules allow users to modify a texture at any specific location. This technique might be used to make textures transparent, thereby allowing the user to see through a given structure. This process can be expensive with regards to system resources and can give unpredictable results when used indiscriminately. Consequently, locations are limited in order to maintain close control on the nature of the models affected by this technique. Any attempt to immerse the user in a large complicated environment such as a city requires a highly optimized system.

The Ygdrasil software has a number of existing modules designed to allow control over the models that are rendered in the scene at any given time. A strategy of replacing models having a high number of polygons with lower resolution models ("level-of-detail") will be used to reduce the load on the graphic hardware when rendering buildings and other objects that are not close to the user or cannot be seen from within the current context.

In a multi-user environment, all potentially rendered models are loaded into the memory and excluded from the rendering process until they are required. Most geometry in the project will be static geometry that appears in the same manner for each user.

Any dynamic changes to these models will use a set of tools that the lead technical advisor developed last fall. It allows for the material properties, textures, and vertex coordinates of models to be changed in real-time. Although these changes must be propagated to each client site, they are performed through simple parameter changes such as material color, texture position, and geometric interpolation position.

In addition, a digital readout was desired to indicate where the user was pointing. In the past, a module would be written to determine the location of the hand-held wand (a three-dimensional input device used by people in the

CAVE), transform it into its grid coordinates and then manipulate the object located where the user was pointing. For this project, a module that determines the intersection position of any wand was created. This output was routed to an interpolating module that converted the result into grid coordinates. The grid coordinates were then routed to a module capable of displaying the output.

"Heavy" data transfers (such as whole models and textures) are avoided whenever possible. In the event that new content is created, as in the case of drawing new geometry or taking camera snapshots, Ygdrasil has a system for distributing new content to client sites.

2.4. Ygdrasil Antecedents

2.4.1 Tech & artistic antecedents

The Ygdrasil system grew from software developed for the "Multi-Mega Book in the CAVE" application [1], and was further refined during the development of "Mytologies". These two applications are both large-scale environments that involve hundreds of models, texture maps, and audio clips; the environments cover a large virtual space, and include multiple scenes. Most of the artists involved were experienced with tools such as SoftImage, Photoshop, or MAYA, but were not expert computer graphics programmers.

EVL has focused much of its research into developing tools and techniques for generating interactive virtual environments. For many years, EVL computer scientists and artists developing virtual-reality applications used the C and C++ languages. Routinely, these applications were “one-off” pieces that were written from the ground up. Frequently, one virtual-reality application did little but serve as an example to other programmers. Graphics and interactive elements were hard coded into applications that had little flexibility outside of recompilation. Many artists are interested in creating virtual-reality art pieces but are daunted by the complex computer coding required. Typically, artists work with engineers, but this scenario often does not give the artist the opportunity to experiment and work in a “hands-on” fashion with the application. Additionally, an engineer’s time can be expensive. XP, a framework for virtual environment applications, was designed to alleviate these problems. [2] With this system, which eventually became Ygdrasil (YG) and the subject of his dissertation, Dave Pape developed a modular system of components that could be configured into a working virtual-reality system through the use of text script.

2.4.2. Hardware and Software Systems

The original CAVE® applications were developed using hardware and software developed by Silicon Graphics Corporation (SGI), in conjunction with EVL-developed CAVELib® software. CITYCLUSTER was started using SGI’s IRIX operating system and OpenGL Performer. SGI’s Performer scene graph library is a groundbreaking graphics library that was the first to introduce scene graph rendering along with multiple real-time optimization techniques such as multi-pipe graphics rendering. Recently, the software used to develop CAVE® applications has been ported to the Linux operating system. Today, CAVE® installations, such as the one housed by the Ars Electronica Museum of the Future in Linz, Austria, are being retrofitted to use Intel X86 architectures and commodity graphics cards. The transition to Linux-based systems has seen great increases in the metrics of graphics texture memory, polygon fill rate, and CPU speed. In turn, the development of CITYCLUSTER was migrated to the Linux platform where execution speed and startup time greatly enhance the development process.

The Ygdrasil software system is designed to run on Silicon Graphics (SGI) and Intel X86 hardware under IRIX and Linux operating systems, respectively. The system is built on top of SGI’s OpenGL Performer scene graph library. Ygdrasil requires EVL’s CAVELib® and the CAVERNsoft® (now Quanta) networking library. CAVELib® is currently a commercial product distributed by VRCO, and CAVERNsoft® is open source and available on the web <www.cavernsoft.org>.

3. META NET PAGE: virtual-reality networking interface display

3.1 Meta-Net-Page Features

The Meta-Net-Page (MNP) is a virtual pathfinder, able to detect information, images and details that are invisible zones or intangible realities for the naked eye. It indicates the current user coordinates and provides more detailed information about the objects within its view. The Meta-Net-Page allows a user to zoom in or out by moving a view panel closer or farther away from his or her own eye. It includes interactive buttons for accessing several functions available to the user. The user will be able to fly up into the sky to gain a greater overview of the city they are currently exploring. The user can "teleport" immediately to the location shown on the view panel; it is also a collaborative networking camera. Visitors from the different sites see, manipulate and interact through the same virtual interface.

Figure 2, 3. Interacting with Meta Net Page over the network

The visitors can "take pictures" and store them. These snapshots serve as placeholders for specific locations and headings. When desired, two users can collaborate to return to a particular location by moving one view panel over another. The Meta-Net-Page allows the user to "grab" onto a building shown within the panel and moves it to another location or even to another city. The user can also capture a selected number of textures for later application to other buildings.

The Meta-Net-Page also acts as a sort of mirror. The visitor can reflect his or her avatar in it by turning it around toward himself while he is within the virtual environment. The avatar of each user is not normally shown, only the Meta-Net-Page of each user is visible. This mirror feature allows the user to show other users what they really look like.

3.2. Navigation with the Meta-Net-Page

Meta-Net-Page aids the user in several interaction modalities. Navigation techniques in virtual reality include “gaze-directed” navigation, “target-selection” teleportation, and “grabbing-the-air” movement, to name a few [3].

Although no empirical research has been done to verify the utility of our method, anecdotal evidence suggests that Meta-Net-Page is an improvement upon methods that cast a ray, like a laser beam, to a location and then teleport the user to that location.

Prior methods have either utilized head tracking or wand tracking as the source of the ray being cast. Methods that use head-tracking information suffer from the problem that the first-person perspective of the user is co-opted for the interface.

As a result, the user cannot attend to other information in the environment while navigating. Furthermore, such systems require that some sort of cross hair be introduced into the user perspective in order to allow for high accuracy. This introduction of user interface elements into the perspective of the user may be seen as a biological integration of user interface elements. Although such a technique is not without merit, it represents a significant design choice and may interfere with the sense of presence that virtual-reality researchers and artis ts seek. Finally, the disconnection between the viewer perspective and the source of the ray being cast hampers methods that use the wand to point at a desired navigation location.

This disconnection is a direct result of the introduction of extra degrees of freedom within the virtual environment. And, it is exactly for this reason that projecting the desired location onto the surface of the Meta-Net-Page has proven more effective than wand-pointing methods. Our method appears to be an improvement because of the direct relationship between the cross hair within the Meta-Net-Page and the perspective presented within its window.

3.3 Collaboration with the Meta-Net-Page

Several other features of the Meta-Net-Page take advantage of the third-person perspective. The interface lends itself readily to the role of camera or video recorder, framing and capturing images as desired. Moreover, the alternative perspective allows the user to see not only context-related information, but also completely different views of the world.

Figure 4, 5. Interacting with the META NET PAGE in Florence environment.

One can easily imagine infrared, x-ray vision, wire-frame, and other novel visualizations of the virtual environment. An engineer interested in structural properties of a design might want to view the objects in the environment with a completely different filter than that of a designer. Several researchers have suggested that having different views of the virtual environment might aid workflow. [4]

The Meta-Net-Page also addresses a key issue related to collaborative interaction. When different filters or views of the environment are projected in first-person perspective or in an additional interface such as handheld or external display, the other users sharing the virtual environment do not have access to it.

EVL researchers under the direction of Jason Leigh are actively researching the benefits of networked collaboration by gaining access to information presented to each user within a virtual environment [5].

The design of the Meta-Net-Page lends itself directly to this function by simultaneously displaying context-sensitive information available to the user along with the information displays of all other users within the same virtual environment.

In addition Meta Net Page allows users to grab buildings and move them to another location or even another city. This functionality contributes to the mutual understanding across cultures by allowing users to see a building in a completely different context. The Sears Tower, for instance, when placed in Florence, immediately imparts an understanding of the different context within which Florentines and Chicagoans live.
When coupled with the ability to capture pictures with the Meta-Net-Page, users can compare the changes they have made to their environment with images of their environment before or after the changes. Unlike most cameras, the Meta-Net-Page allows the user to teleport to the exact location and orientation from which the image was taken.

A user selects a building by framing it within the cross hairs of the view presented by the Meta-Net-Page. The user then moves his or her hand to the "grab/select" button. When the user physically presses the actual button on the wand, a small image appears in the center of the Meta-Net-Page and grows to become a three-dimensional model of the building. All information presented on the Meta-Net-Page, including the wand-over, selection of user interface buttons, and the first-person perspective view, is visible and therefore understood by all participants.

3.4 Co-location within Multiple Cities

CITYCLUSTER creates the illusion that multiple users are simultaneously visiting multiple co-located cities. This means that there is a fixed correspondence between positions on a grid and the buildings and features of each city. Several techniques were used to accomplish this goal, including teleportation, objects common to each city, and walking through walls.

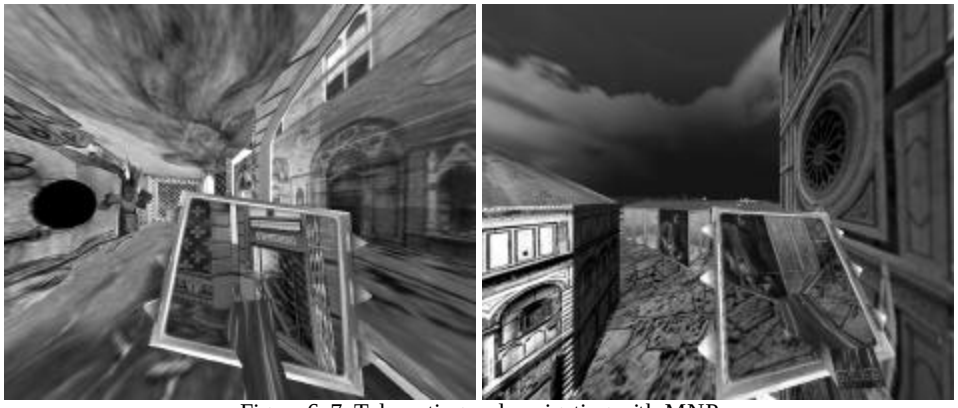

Figure 6, 7. Teleporting and navigating with MNP

The primary means of re-enforcing the concept of multiple co-located cities is the alternate viewpoint displayed on the Meta-Net-Page. When a user in Florence encounters a user in Chicago, he will see a view of Chicago in the Chicago user's Meta-Net-Page device. Teleporters are placed throughout the environment to allow users to move between the two cities. To a user watching another user walk through a teleporter, little will appear to have happened with the exception that the view within the Meta-Net-Page changes to that of another city. Teleporters are also placed at interesting locations to re-enforce co-location. In one example, a user traveling to the top of the Giotto Tower is teleported to Chicago only to find himself on the sixth floor of an office building.

Another special-purpose module created for the project allows a texture to be superimposed upon another texture. While this functionality is commonly used in videogame systems, it was desired that the secondary texture be transparent and allow the temporary viewing of objects behind the existing geometry. A technique called sub-texture loading, a process well implemented in hardware on modern graphics cards, was used to achieve this goal without incurring a large performance penalty. Again, artists who might want to create bullet holes, tears, or other X-ray-vision related features designed the module in a manner that facilitates reuse. This module was used to create a silhouette of each avatar as they walk through walls in each city. This silhouette creates a perforation in the wall

in the shape of the avatar. When not assuming the personality of one of the CITYCLUSTER avatars, the user makes an impression commiserate with the image they see when using the Meta-Net-Page as a mirror.

Finally, placing some objects in all environments at once elucidates co-location. These objects can be picked up by a user in any city and moved to another location within all cities at once. For example, the planes generated by the Machiavelli avatar fly out from the user and take their place within the city of Florence. Yet, at the same time, a user in Chicago also sees the planes fly out over the city and take their place in the same locations in Chicago.

3.5. Creating the Meta-Net-Page

The Meta-Net-Page was initially conceived as a user interface tool, a tool through which the user could access a great array of functionality. Traditionally, user interaction with CAVE® virtual environments has been mediated by the "wand," specialized hardware that includes several buttons and a joystick. The wand is tethered and tracked just like the head. Using button presses for user interaction within an environment can be very effective, but the limited number of buttons and the limited ability to remember the function of each limit interaction. Because the computer is tracking the position of the wand, it can be used as a mouse or cursor. Many 3D menu systems for virtual environments have been proposed, but most have proven awkward in practice.

The Meta-Net-Page provides a number of buttons by redefining each button on the wand. The function of each button is illuminated by a graphic that appears within the window of the Meta-Net-Page.

A special module was created for Ygdrasil that can render any scene from any desired viewpoint. In order to keep the module as general as possible, the module was created in a manner such that the result of this alternate view could be directed to any existing texture within the application. This modularity will allow future users to take advantage of the functionality created for this project.

Meta-Net-Page mirrors the current trend towards ubiquitous personalized devices like the PDA and cell phone. Increasingly, these devices serve as mediators with our everyday environment, providing not only communication, but also giving information in context to their location in the environment and serving to interface devices in their presence. Perhaps the best examples of these trends are GPS location-based services that find entertainment venues and cell phones that can purchase items from vending machines. The Meta-Net-Page acts as a large digital viewfinder similar to those found on the back of digital cameras. The device provides contextual information and functionality within the virtual environment. For example, the name of a building is presented when a building is located within the cross hair of the viewfinder. In addition, context-related functionality; such as teleportation to the location in the cross hair, is also implemented. Similarly, the selection of buildings for relocation is accomplished in this manner. The Meta-Net-Page also lends itself to use as a camera, framing and capturing snapshots that uniquely allow the user to return to the original position and orientation from which the image was taken.

Figure.8, 9. The Meta-Net-Page acts as a large digital viewfinder

While pointing to objects and accessing context-related information and functionality are trademarks of most modern interfaces, it has traditionally been accomplished from first-person perspective in virtual reality. The inclusion of a third person perspective into the virtual environment addresses a long-standing interaction problem. User interface researchers such as Donald Norman have pointed out the utility of constraints in interface development [6]. A significant factor in the success of the two-dimensional graphical interface has been the constraints provided by the limited degrees of freedom. Interaction processes that are efficiently carried out in two-dimensional space suddenly elicit great frustration in three-dimensional space. Projecting three-dimensional space into a two-dimensional space reduces the degrees of freedom and allows the user to regain the dexterity of simple two-dimensional interfaces while retaining a first-person perspective on the scene. This technique has been used with success by other researchers in the form of shadows cast onto orthogonal planes within virtual environments [7].

3.6. Further comments: collaborative virtual environments

Research into projection based virtual reality at EVL evolved to include a technology called tele-collaborative virtual reality that connects each CAVE system together via high-speed networks. The CAVERN® software library, along with efforts by other researchers in the field [8], seeks to coordinate user actions so that the state of each CAVE virtual environment is synchronized. This creates the illusion of a shared virtual space by transmitting the actions of each user, such as grabbing and moving an object, to the participants in each CAVE®.

Often artists envision virtual environments that break the model upon which networked virtual reality was founded. An artist may want to create an environment where each user perceives the actions taken by one user differently. The EVL laboratory has a 30-year history of interdisciplinary collaboration between artists and computer scientists. Research at EVL has driven the development of software tools that relieve the technical burden of creating interactive virtual environments.

Contemporary concepts of collaborative virtual environments (CVE) are often based on the assumption that participants seek to work together on a task that involves cooperative turn taking and requires mutual awareness of user intentions and actions [9].

However, the definition of collaboration can also include broader and more humanistic actions, such as the creation of spaces within which we live and operate. Although we can surely say that we collaborate to create urban environments in which we live, this form of collaboration is not always marked by cooperation and mutual awareness.

We can also say the same thing about virtual spaces we create Often, these spaces and the tools to manipulate them, such as chat rooms, web logs, or other online communities, are simply created to establish the space with little knowledge of how they should be, or will be, used.

Among the goals of CITYCLUSTER are to improve upon the existing set of tools available to artists creating virtual environments in order to allow them greater flexibility. Innovative techniques for representing multiple alternative perspectives within a virtual environment were created as a result of the collaboration between artist and scientist. Re-enforcing the illusion of multiple environments co-located within the same virtual space motivated the development of new tools for manipulating textures. Furthermore, new techniques for object selection and user navigation were developed as a result of the CITYCLUSTER project.

4. "FROM THE RENAISSANCE TO THE MEGABYTE NETWORKING AGE"

4.1 Concept

"From the Renaissance to the Megabyte Networking Age" is the first CITYCLUSTER virtual-reality networked application. The CITYCLUSTER cities of Florence and Chicago are characterized by multiple narrative spaces that comprise animated sculptures, interactive phenomena, high-tech performances and characters of distinct and peculiar behavior. Emphasis is on aesthetics and content quality, visual design, perspective and intense interaction, thus bringing out the content to its fullest expression.

Navigation and interaction are often surprising. The interactive visitor can find himself within a sort of limbo state where reality, the oniric and the imaginary exist simultaneously. The surprise factor in relation to body space and to the absence of temporal schemes is considered a pivotal experience among remote CITYCLUSTER visitors. This creative approach allows multiple viewpoints and repeatedly generates an original multi-linear participatory interactive experience for the visitor.

Buildings become cyber-gateways, teleporting visitors from one city to another. Renaissance or Megabyte digital interactive fragments are found strewn across the virtual cities or floating randomly through the atmosphere. When a visitor interacts with them, the environment undergoes transformations. Masterpieces morph into three-dimensional creatures. The city itself can morph into a painting, transparent and penetrable, hosting a myriad of ethereal elements.

The application is a large-scale environment articulated by multiple legendary buildings and architectural structures: The Academy, Picasso statue, Cathedral of Santa Maria del Fiore, The Baptistery, Giotto's Bell Tower, Lorenzo the Magnificent gallery, Hancock skyscraper, Sears skyscraper, the bridges of Chicago. Each component of the environment covers a large virtual space, using hundreds of megabytes for models, texture maps, and audio clips to link multiple scenes.

4.2 Virtual scenarios

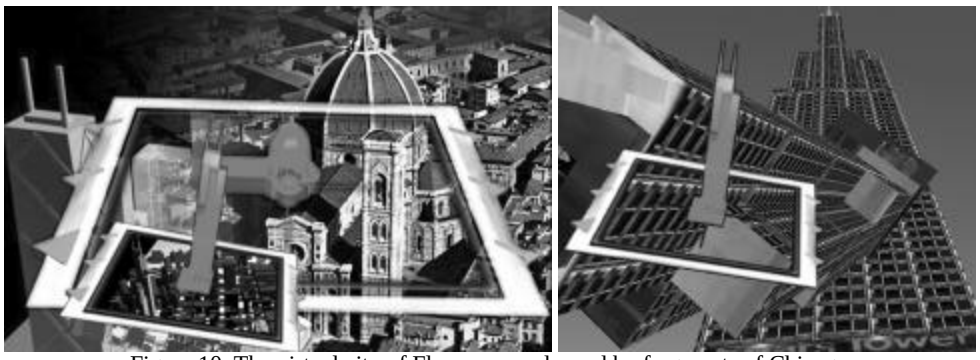

Figure 10. The virtual city of Florence overlapped by fragments of Chicago
Figure 11. Detail of the Sears Tower constructed in 1974 at Chicago, 442 meters/1450 feet high

4. 2.1 Florence

The virtual city of Florence appears luminous with golden brush strokes seeming to radiate light from within. The Renaissance virtual environment allows a wide range of actions, space transformations and the entwining of time and space. Objects and interactive creatures of peculiar behavior, such as Diavolis Nerboroti, Nety screens and Gigabits digital fragments exist within the virtual city of Florence. The avatars Venus, David and Machiavelli, as

well as other selected elements and personages extracted from other outstanding works of art from the Renaissance period are found within.
The buildings and squares that dominate the scenery are the Palazzo Vechio, the Cathedral of Santa Maria del Fiore and Brunelleschi's Dome, the Baptistery, The Giotto's Bell Tower, Uffizi Gallery, the Palazzo Medici Riccardi, Santo Spirito, Ponte Vecchio, Chiesa di Santa Annunziata, The Academy, Piazza del Duomo, Piazza Signoria and others.

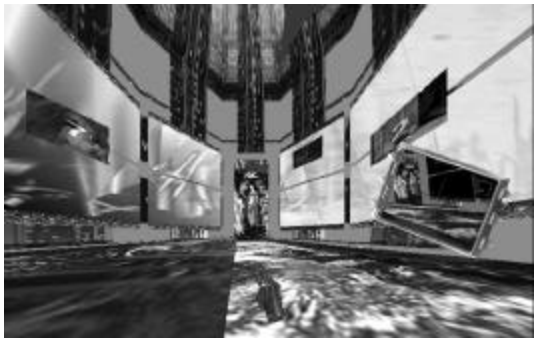


Figure 12. In CC, the legendary room like the "Tribuna" becomes a cyber gateway
Figure 13. Upon visitor navigation personages of the pictorial cycle is the Final Judgment, such as the angels the 'Diavolis Nerboroti', can be found in diverse places of the Cathedral.

4.2.2 Chicago

The virtual city of Chicago appears under an unreal atmosphere, immersed within a cold-bio and gelid environment; a sort of a silver watercolor with strokes of metallic light and blurry outlines. Contrasting against this landscape, some of the most outstanding buildings of the city, such as the John Hancock building and Sears Tower, emerge as volumetric and realistic forms, filled with intensely luminous light. Depending on a visitor's interaction, the shoreline of Lake Michigan can become a dense accumulation of optic fibers of diverse colors, intensity and luminosity. The city generates musical sounds and other audio effects. The virtual city of Chicago hosts a myriad of character avatars and phenomena, each acting according to its individual nature and personality.

The buildings dominating the cityscape are the John Hancock building, Sears Tower, Water Tower, Harold Washington Library, Merchandise Mart, the Chicago Tribune Tower, Chicago Board of Trade and the Art Institute of Chicago. The buildings are interactive elements and places in which digital effects take place, responding to the navigation and interaction of the visitors. The public sculpture of Picasso, Miro and Calder, all symbols of Chicago's cultural heritage, are a vital part of the virtual environment as well.

4.3 Exchanging Buildings and Architectural Elements

CITYCLUSTER allows users to grab buildings and objects and move them to another location or even another city.

The Dome of Florence, for example, can be transported to Chicago, or the Sears Tower to Florence and so forth. Buildings may be moved to create a new city or urban environment containing elements of Chicago and Florence. To facilitate moving objects of such scale, users can elevate themselves to a position above the city. Architectural building textures can be captured like the sampling of a color to be applied later to buildings in another city.

A user selects a building by framing it within the cross hairs of the view presented by the Meta-Net-Page. The user then moves his or her hand to the "grab/select" button. When the user physically presses the actual button on the wand, a small image appears in the center of the Meta-Net-Page and grows to become a three-dimensional model of the building. All information presented on the Meta-Net-Page, including the wand-over, selection of user interface buttons, and the first-person perspective view, is visible and therefore understood by all participants.

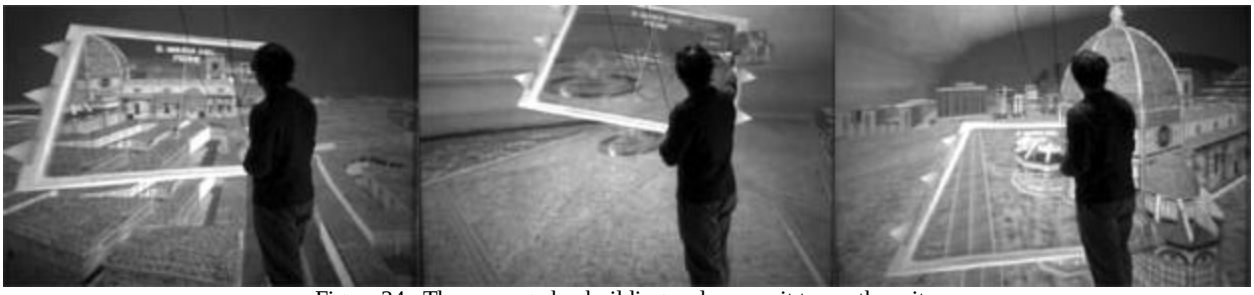

Figure.24. The users grab a building and moves it to another city

This functionality is not only interesting, but contributes to the mutual understanding across cultures by allowing users to see a building in a completely different context. The CITYCLUSTER project seeks to create a framework within which a single urban virtual space can be formed. This framework relies on the idea that multiple cities, each with their inherent cultural contribution, can be co-located in a single virtual territory. The Sears Tower, for instance, when placed in Florence, immediately imparts an understanding of the different context within which Florentines and Chicagoans live. When coupled with the ability to capture pictures with the Meta-Net-Page, users can compare the changes they have made to their environment with images of their environment before or after the changes. Unlike most cameras, the Meta-Net-Page allows the user to teleport to the exact location and orientation from which the image was taken.
By giving users the tools to exchange cultural artifacts, such as legendary buildings and trademark architectural motifs between cities, we hope to transform digital technology into a more humanistic instrument of communication that highlights the various relationships shared among cultures.

4.4 Avatars

4.4.1 Concept and design

The avatars represent the visual and graphic concepts and symbols of diverse ages. Each virtual city is inhabited and guided by a group of avatars: Mega, Giga, and Picasso are the avatars representing the Gigabits Networking Age, while David, Venus, and Machiavelli is a Renaissance-age avatar. Visitors contact and interact with each other in more expressive ways through the avatars. Each avatar represents a real person in cyberspace, acting as a "virtual representative" able to communicate with others in the environment. Through the avatars, CITYCLUSTER's visitors see and experience a projection of themselves into a virtual body, or altered presence, in another environment, enabling them to interrelate, interact, and become immersed within this altered physical reality.

David, Venus and Machiavelli are 15th-century sphinxes, historical icons, narrative myths conceived, sculpted and enriched by the collective imagination that today forms part of the pantheon of figures related to the "rebirth" of art in Italy. This rebirth was connected with the rediscovery of ancient philosophy, literature, artistic styles and science as well as the evolution of empirical methods of study in these fields. The Renaissance was a period characterized by humanism, innovation, science, myth, beauty, aesthetics, politics and power.

Mega, Giga and Picasso embody the Gigabits Networking Age, a time in which the invisible is no longer formless. These avatars symbolize our age of meta-communication and the abstraction of representation, the electronic era, high-speed power, politics, networking, tele-presence, cloning, fear and networking. It is an age in which the act of communication is rapidly shifting in radical ways and the possibility of experiencing the intangible increases as the invisible takes form. This is also an age in which it is now possible to conceive of oneself as both a digital and analog being. The distinction between selfhood and facsimile collapses, as does the notion of fiction and reality. One need not experience an event as a physical body, if in fact one is able to experience that event as a temporal body in real time. Presence does not rely upon bodily inhabitance. This is the new reality of the Gigabits Networking Age.

By taking this specific approach to the concept of the avatar, the aim is to imbue the unique traits of each city by allowing participants to assume the identities of important protagonists in the history of each city. When assuming the role of one of these avatars, a user can see the environment through another set of eyes. Buildings and spaces change and distort to reflect the unique contribution of the avatar embodied at that time, and the user gains unique abilities to change the environment and navigate previously undisclosed locations within it

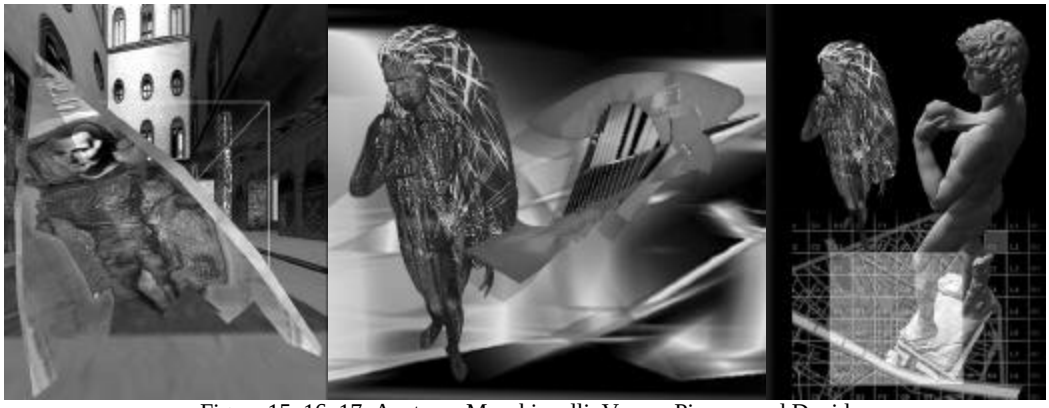

Figure 15, 16, 17. Avatars: Macchiavelli, Venus, Picasso and David

4.4.2 The Renaissance Age Avatars: Description &Interactivity

David

The David avatar was inspired by Michelangelo's sculpture of the Biblical hero, David. In the virtual city of Florence a facsimile of David stands in front of the Palazzo Vecchio in Piazza Signoria, at the center of Florence as a sort of ghost-like plasma, a multi-layered three-dimensional composition.

When a visitor chooses David as avatar, the David sculpture shrinks and a spherical screen appears on the top of his head on which thoughts and visions are reflected. After becoming David, the visitor can step into the shrunken sculpture and be teleported to a time tunnel, eventually arriving into the Academy, in front of the original three-dimensional David. The time tunnel is a composition of a cyber-Renaissance architectonic structure interspersed with details of Michelangelo drawings. David has multiple features and interactive behavior.

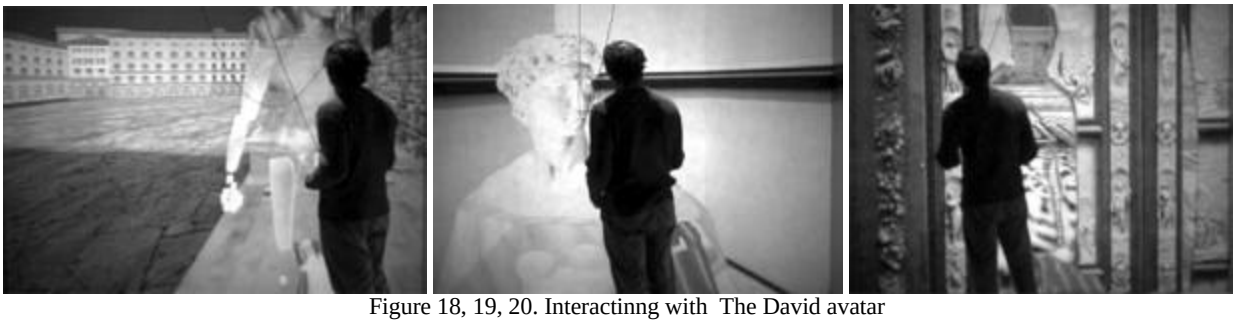

Figure 18, 19, 20. Interactinng with The David avatar

Venus

The Venus avatar was inspired by the subject of Botticelli's painting "The Birth of Venus". In the virtual city of Florence, Venus is sensual and enigmatic, enhancing the feminine spirit of the city and demonstrating Renaissance ideals of beauty. Unlike David, Venus represents not a Christian legend but a classical myth. To the Renaissance mind, the mythology of the admired Greeks and Romans represented something more than gay and pretty fairy tales. So convincing was this mythology of the superior wisdom of the ancients that many during the Renaissance

believed these classical legends must contain some profound and mysterious truth. Botticelli's painting was made for the Villa of Lorenzo di Pier Francesco de' Medici and is now in the Galleria degli Uffizi in Florence.

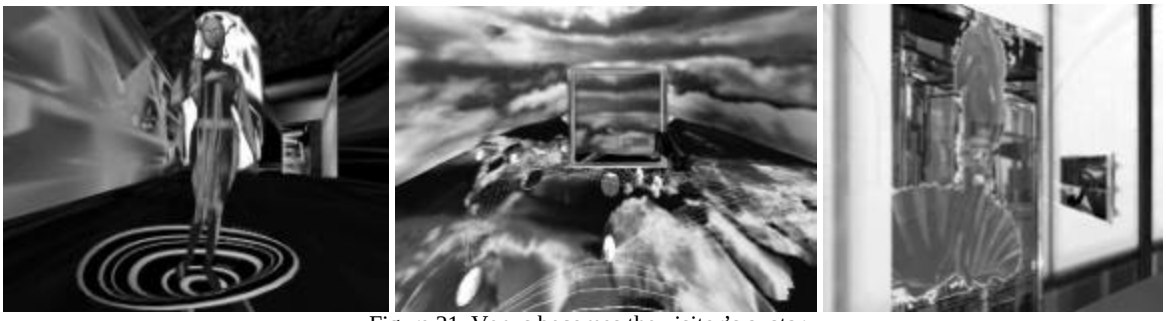

Figure 21. Venus becomes the visitor's avatar
Figure 22, 23. Interacting as Venus Avatar

The CITYCLUSTER visitor meets Venus upon entering into the "Piazzale degli Uffizi", where Venus' shell descends from the sky. The visitor can step on to the shell, fly up and penetrate the walls of the Uffizi Gallery. Once inside, the visitor encounters the painting, "The Birth of Venus". While the visitor gets closer to the painting, the painting absorbs Venus's shell; Venus vanishes from the painting and rises out of the water as a 3D cyber-Venus to become the visitor's avatar. The visitor, now as the Venus avatar, can penetrate the painting, which morphs into a three-dimensional environment: Earth and Ocean. The visitor can navigate around the planet and interact with the satellites.

The Venus avatar possesses specific characteristics and features, and depending upon navigation and interaction, she will cause events to happen and phenomena to materialize in the virtual-reality environment around her.

Machiavelli

The Machiavelli avatar represents power, luxury, high-end technology, politics and fear. The avatar is inspired in the figure of Italian statesman and political philosopher Niccolò Machiavelli, author of "The Prince" (1513), is unquestionably one of the most relevant symbolic representations of modern concerns: power, politics, and domination.

Figure 24. Palazzo Vecchio Courtyard

The visitor encounters Machiavelli in the Palazzo Vecchio courtyard, the Florence City Hall at the Piazza Signoria. Once the visitor enters the courtyard, Machiavelli's multilayered portrait rises up on top of transparent layers, picturing a premonitory creature looking down over the a map of Florence. Once the visitor gets near the figure, the layers vanish and Machiavelli becomes a three-dimensional aerodynamic figure. In that moment, the Florence city map scales into a red interactive platform while Machiavelli morphs into a sort of black bird, a warplane that explodes decomposing and recomposing itself flying toward the visitor to become his avatar. Suddenly, the visitor sees himself embedded in Machiavelli's avatar (inside a cockpit), the Florence city map becomes a ramp, moving

the Machiavelli avatar up above the city. Once up, a formation of 16 airplanes departs from the platform with their destination into the city. The visitor has two choices: to teleport back to Florence or to fly to Chicago. If the visitor selects America, he wills teleport; the flight targets Sears Tower. Only a few seconds before an imminent crash, the Machiavelli avatar lands safely on top of the Sears Tower.

4.3. The Gigabits Networking Age Avatars: Description &Interactivity

Mega

The Mega avatar is a sort of compressor, akin to a high-voltage electrical stream; its movements resemble those of electrical signals. It rises to unimaginable dimensions when it has accumulated an abundance of information and floats, enormous and pompous, in space until the visitor decides to interact with it. Mega is a metamorphic avatar whose constant transformation depends upon gathered information. Mega's behavior is multiple: appearing at times as a stream of electricity, it acts as an avatar as well as an interactive guide for the visitors.

Giga

The Giga avatar is composed of chromed geometrical forms that shift to create a digital interactive sculpture. Giga appears first as a sculpture on whose surface is reflected digital information that passes by as high-resolution random images. As a visitor approaches, Giga opens and becomes a screen, initiating an interactive relationship and guiding the visitor through the environment. She is a networking agent acting as an information carrier; she sends and receives information, transforms the environment, and projects images and representations onto its surface.

Picasso

The Picasso avatar was inspired by Picasso's unnamed sculpture, often refereed as Chicago Picasso, located in downtown Daley Plaza. A visitor gazing upon the statue from another location sees the statue breaking into pieces, shrinking to human scale, and moving onto the visitor's head, body, and hands. What appears to be the face of the statue becomes a pair of wings, moving softly upon the back of the avatar. Stepping into the now semi-transparent remnant of the original statue, the user is taken on a journey through the streets on Chicago that ends in the main gallery of the Art Institute.

4.4.3. Further comments: Self-Reflective Avatars

The use of avatars plays a significant role in the ability of participants to interact with one another. An avatar is the prime mediator of actions, intentions, focus, and intentions of other participants in the virtual environment. Research at EVL has explored avatar features that include articulated body parts, moving mouths, and even video feeds of users projected onto neutral surfaces [10].

Initially, artistic endeavors in collaborative virtual environments consisted of multiple users interacting with the virtual art piece synchronously. In 2001, EVL presented "Alive on the Grid" at the Ars Electronica Festival in Linz [11] Austria. This piece was a technical success; in that it was a proof of concept that seven CAVE installations around the world could be connected using Ygdrasil software. Although this piece did not include environments that required the presence of other users for interactive elements, it did make a significant contribution to the development of the avatar. A small portion of the piece, called the "Dressing Room", allowed a user to choose body parts, including realistic representations of the artists' faces, to create their own customized avatar. While selecting ones own avatar was not unique, the piece included several mirrors in the room to allow the user to reflect upon his or her representation. It quickly became apparent that the ability to see oneself in virtual reality was a compelling concept.

In an effort to expand upon this theme, we sought to play with the representation of the user between distributed virtual environments. In CITYCLUSTER, a user sees a different virtual representation of himself in his Meta-Net-Page than what is seen by another user. In fact, after assuming the persona of one of the characters in each city, the user still finds that his Meta-Net-Page appearance has not changed. In effect, his perception of himself has not changed despite the identity that he has assumed. It is only through images captured by another user's Meta-Net-Page that one can see how others perceive him. In this way, CITYCLUSTER is only valid when multiple networked users cooperate with one another to realize these images.

5. GOALS

- To build a technological and conceptual framework, using international networks and virtual reality, within which multiple cities clustered in a co-located space to enable creative interdisciplinary remote collaboration that highlights relationships shared among cultures.

- To explore the possibilities derived from the fusion of digital media, culture, art, literature, myth and cinema and to expand the ability to conceptualize, communicate and enrich human interaction.

- To implement a VR net art piece were Visitors, with their virtual bodies become active protagonists in a virtual terrain. Were they are bale to be free to communicate, intervene, share viewpoints, exchange knowledge, ideas, buildings, objects, build a new shared virtual ambience, recreate a new city or design their own

- To explore the opportunities offered by advanced information technology in order to support natural interaction between human beings and a digital system for the fruition of artistic content.

- To further refine software tools and techniques that aids the rapid and intuitive development of interactive virtual environments for artists and other non-technical users.

5. DISCUSSION AND FUTURE WORK

The CITYCLUSTER project is an ambitious project that seeks to create a large amount of highly interactive content. The models created for the first phase of the CITYCLUSTER project was developed by an interdisciplinary team. However, the interactive content was generated solely through the interaction between the artist and a single programmer. This, along with the success of other projects using the Ygdrasil software, has shown that the development environment facilitates the creation of large amounts of diverse interactive content for virtual environments.

The results of the first CITYCLUSTER project, "From the Renaissance to the Megabyte Networking Age", have been fruitful. The application has been shown at a number of venues, including the Ars Electronica Festival in 2003, and remains there as a permanent installation. In addition interesting concepts such as self-reflective avatars, novel navigation techniques and user interaction devices have been explored. The goals of creating a unified interaction tool and methods for re-enforcing co-location within the multiple co-existing environments have been achieved. The result is a compelling interactive virtual-reality art piece that serves as a starting point for which to include more cities.

In addition, a potential enhancement to CITYCLUSTER includes the development of a tool for authors and producers to create Immersive Interactive narrative forms, and a more artistic and intuitive approach for multi-linear participatory interactive experiences.

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References

[1] Pape, Dave, Tomoko Imai, Josephine Anstey, Maria Roussou, Tom DeFanti, "XP: An Authoring System for Immersive Art Exhibitions", Proceedings Fourth International Conference on Virtual Systems and Multimedia, Gifu, Japan, Nov 18-20, 1998.
[2] Anstey, Josephine, Dave Pape. "Animation in the CAVE." Animation World Magazine, Vol. 3, No 1. April 1998
[3] List of Common Interaction Metaphors, UCL React/Interact Project, http://www.cs.ucl.ac.uk/research/vr/Projects/Interact/Glossary.htm
[4] S. R. Fussell, R.E. Kraut, J. Siegel, "Coordination of Communication: Effects of Shared Visual Context on Collaborative Work", Proceedings of CSCW, pages 21-30, 2000
[5] Kyoung S. Park, Luc Renambot, Jason Leigh, Andrew E. Johnson, "The Impact of Display-rich Environments for Enhancing Task Parallelism and Group Awareness in Advanced Collaborative Environments ", Workshop on Advanced Collaborative Environments, June 22, 2003
[6] Norman, Donald A. The Psychology of Everyday Things, New York: Basic Books, 1988
[7] The Living Worlds VRML Working Group, Living Worlds Specification draft 2, http://www.web3d.org/WorkingGroups/living-worlds/draft_2/index.htm
[8] D. Sandin, S. Subramanian, et. al., "A Realistic Video Avatar System for Networked Virtual Environments", 7th Annual Immersive Projection Technology Symposium, 2002.
[9] C. Gutwin, S. Greenberg, M. Roseman, "Workspace Awareness for Groupware", CHI Conference Companion, pages 208-209, 1996
[10] K.P. Herndon, R.C. Zeleznik, D.C. Robbins, D.B. Conner, S.S. Snibbe, and A.van Dam. Interactive shadows. *UIST '92 Proceedings*, pages 1-6, Nov. 1992