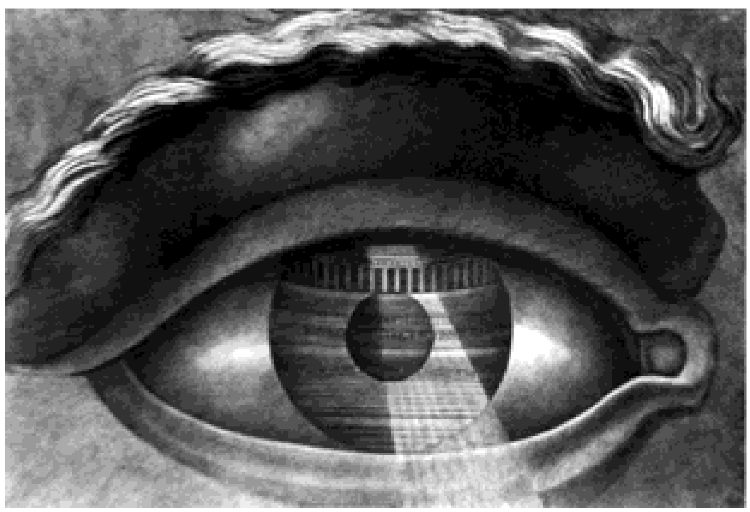
# A LANDSCAPE DATABASE INTEGRATING PHOTOGRAPHIC VIRTUAL REALITY

**Michael Zajac**



Claude Nicolas Ledoux, *The Creating Eye* , 1804

Submitted to the Faculty of Graduate Studies in partial fulfillment of the requirements for the degree of Master of Landscape Architecture

Department of Landscape Architecture
University of Manitoba
Winnipeg, Manitoba

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# ABSTRACT

Methods for representing a landscape using computer databases have almost universally suffered from several shortcomings. Geographic Information Systems (GIS) and related types of mapping systems are expensive and difficult to use. They require a specialist's knowledge of cartography and mapping systems, and often need an operator to have extensive training in technology, in addition to professional knowledge in the field of study. Finally, traditional GIS lacks the capability to represent the landscape visually, in a way that is useful to landscape architects and planners who must deal with visual and aesthetic issues.

Recent developments in landscape visualization have been in the realm of deterministic 3D modeling. These systems are poorly suited to representing landscape at the site scale.

Immersive imaging, in the form of panoramic tapestries, murals and dioramas has been used as a medium for representing visual and qualitative aspects of landscape since ancient times. Roman panoramic wall paintings, the Bayeux Tapestry and Michelangelo's Last Supper are well-known examples. At the end of the eighteenth century painted panoramas and dynamic dioramas entered the realm of technological development for popular representation of landscapes and events. Since then panoramic photography and 'omnimax' theatre have

directly extended this development. Recently, computer techniques have allowed immersive imagery and photographic virtual reality (photo VR) to be produced inexpensively and used on the desktop.

The tight integration of photo VR into a GIS' content and interface supports all of the characteristics of a landscape GIS, provides new information management capabilities and unprecedented accessibility. It allows the GIS to reveal an image of the landscape that has previously eluded the developers of tools for landscape design and planning.

# INTRODUCTION

This project stems partly from my frustrations with most of the available implementations of geographic information systems (GIS). GIS is an invaluable tool for landscape architects and planners, and also for geographers, geologists, epidemiologists, sociologists, anthropologists, marketers and any other professionals who manages information related to the Earth's surface. Although some of the data models and concepts used to implement GIS' are rather complicated, many of the basic workings are straight-forward and easy to understand by professionals who already work with maps, statistics and databases. A GIS has the potential to become a software staple like much of today's "office" software: word processors, spreadsheets, email clients and presentation programs. Unfortunately, it has remained esoteric and inaccessible.

"Desktop mapping" and other GIS technologies have not become popularized like desktop publishing, desktop 3D modeling and web authoring. As these other technologies have become more accessible there has been a proliferation of applications, both good and bad, effected by a thousands of hobbyists and professionals in other fields. In fact, most GIS' that exist today are run at great cost by specialized GIS professionals on expensive equipment, or simply forgone because they are perceived as too complex, to expensive or too esoteric.

The other main need which shaped this project is the requirement for landscape architects and planners to retain a firm connection to the visual and experiential aspect of the landscape. Professional work often begins with a single visit to the site, and continues in the environment of the studio, with pinned-up photographs used to remind the designer/planner of what the landscape looks like. By including a virtual reality representation into the actual work process, this solution helps incorporate those aspects of the landscape that make it a landscape; more than just a sum of locations, measurements and relationships. The virtual reality representation helps imbue the object of the design or planning exercise with those qualities of place that are difficult to represent as a series of numerical values. And by doing so it also enhances the conventional functions of GIS.

This paper describes a web-based database which has been built using inexpensive, off-the-shelf components. It consists of a walk-around of the site of the St. Norbert Arts and Cultural Centre and ruins of the old Notre Dame des Prairies Trappist Monastery. The web interface allows anyone with a personal computer and modem to walk around a realistic virtual representation of the site, as well as browse and search a relational database of historic photography and interpretive text covering all aspects of the site.

The photographic VR solutions to these two problems are mutually supportive. The familiar World Wide Web-based, VR representation makes a database less intimidating and accessible to the general public—as well as to landscape professionals. This ease-of-use reinforces the VR representation's providing a closer connection to the represented landscape. Conversely, the transparent representation helps visualize the real meaning of the data and relationships within the GIS. By bringing together simple database concepts and a realistic visual representation of the landscape using off-the-shelf web technologies this project can help bring the landscape together with the people who shape it and the people who live in it.

# GEOGRAPHIC INFORMATION SYSTEMS

The common definition of geographic information systems[1] is paraphrased throughout the relevant literature. A representative version:

> *a powerful set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world for a particular set of purposes. . . .*
>
> *Geographical data describe objects from the real world in terms of (a) their position with respect to a known coordinate system, (b) their attributes that are unrelated to position (such as colour, cost, pH, incidence of disease, etc.) and (c) their spatial interrelations with each other (topological relations), which describe how they are linked together or how one can travel between them.*[2]

In landscape architecture, the range of attributes in (b) is being stretched to include subjective values relating to visual qualities and aesthetics. This paper will examine how photographic virtual reality can be used to step beyond current capabilities to handle this kind of data, in the chapter titled Immersive Imaging.

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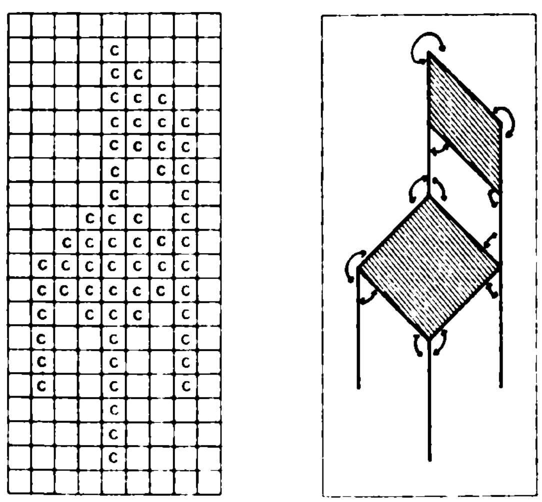
1. Correctly '*geographical* information systems,' but in this paper we will use the much more common term '*geographic* information systems.'
2. See P. A. Burrough 1986, 6.

A GIS does not necessarily comprise computer technology, but today almost invariably does. Usually it is a standard database application, with records containing land attributes. The database records are linked to some type of map graphics, which represent the interrelations between the individual records. The graphics are geo-referenced; that is, their position is defined by a known coordinate system which precisely defines their relationship to locations on the Earth's surface. Most GIS graphics can be classified as either a vector or raster representation of the spatial component.

*Raster and vector representations of the same image. The raster version has a 'resolution' or coarseness, but the vector version is mathematically precise.*[3]



In a vector GIS the graphics use the same technology that is used by Computer-Aided Design (CAD) systems,

3. From P. A. Burrough 1986, 19.

describing graphic objects as points, lines or polygons whose locations are stored as numerical coordinates. In addition to the simple Cartesian coordinate systems that CAD systems use, vector GIS' use one or more standard cartographic coordinate systems (map projections), and can convert between them. Vector GIS corresponds to 'cadastral' mapping, where the land is divided into precise locations, corridors and parcels.

Each unique point, line or polygon on the map is linked to one or more database records. Each 'theme,' or layer of the map is linked to one 'table' in the database. Data in one table may have attributes which correspond to attributes in another table of records. This relationship is referred to as a 'relation,' and this characterizes a 'relational database.'

For example, the database record for each land parcel on a map may contain a field with the name of the land owner. Another table may contain one record for each land owner. A user of the database could select one or more land owners from the list, and use the relation to create a map of all the land parcels they own. Conversely, one could select all the land parcels within 1 km of a proposed development, and use the relation to create a list of all land owners who are required to be informed of the proposal. Through the complex multiple relations that come about in a multi-layered GIS, simple database operations can be used to perform very complex analyses.

A raster GIS, in contrast to a vector GIS, is one that stores map graphics as cells on a square grid. Raster GIS is usually uses data that are produced by satellite images and air photography, collectively called 'remote sensing.' While usually lacking the deep relational aspects of vector GIS, raster GIS is capable of complex graphic operations such as overlay, filtering and enhancement. Raster data usually describes values on a continuous surface, such as reflectivity in one part of the light spectrum, elevation or density.

A GIS may also be able to overlay both vector and raster data, and derive one type of data from the other.

In addition to the data itself and the software used to organize and process the data, a GIS comprises the hardware used to input, store, display the data and software programs. It also includes the people who can operate and maintain the equipment, and make use of the data. Although 'desktop' systems which run on personal computers are becoming more and more common, GIS' often require powerful hardware, expensive specialized software, laboriously-generated data sets and a team of diverse expert specialists, programmers and technicians.

This paper will demonstrate how virtual reality may contribute to implementing a higher-level metaphor in GIS, while helping integrate existing data elements.

# IMMERSIVE IMAGING

## PANORAMAS AND DIORAMAS

Since earliest times, artists have been creating representations of places which comprise an all-encompassing ‘overview.’ Egyptian and Roman wall paintings, the Bayeux tapestry, Baroque *trompe d’oeil* paintings in ceilings and stage-sets, ‘topographical’ engravings of famous cities are all examples which have some characteristic that we may think of as ‘panoramic.’

*Engraving of San Francisco by Charles Meryon. This was executed during the late period of engraving. The image was created from an assembled panoramic photo by Carleton Eugene Watkins.*[4] *The engravers had great difficulty due to the disjointed perspective in the original image.*

However, neither the modern concept of a panoramic vista, nor the word ‘panorama’ existed before the age of the enlightenment. The development of vanishing-point perspective during the European renaissance, the employment of *camera obscura* and the discovery of the horizon by landscape painters helped bring the concept of vista into the popular realm. The development of a middle class with leisure time and a desire to travel to exotic locales and the European obsession with ballooning set up the circumstances into which came the panorama.[5]

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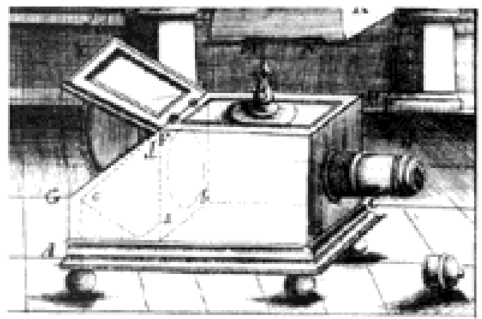
4. From Harris 1993, 88.
5. See Stephan Oettermann 1997.

*The* camera obscura*, invented by Johann Zahn in 1685, projected an image onto a piece of paper to be traced by an artist.*[6]



Documentary drawing and painting in support of the newly developed earth sciences, and the exacting engravings of Charles Meryon provided a model for objective representation of the landscape.

On 17 June, 1787, Robert Barker of Ireland received a patent for a type of landscape painting he referred to as "*la nature à coup d'oeil*." Within a few years he coined the term 'panorama' — from the Greek *pan* (all) and *horama* (view) — to refer specifically to his invention. The word quickly spread into popular usage throughout the world and, long after the decline of the panorama's popularity, continues to be used for wide views, both literally and metaphorically.[7]

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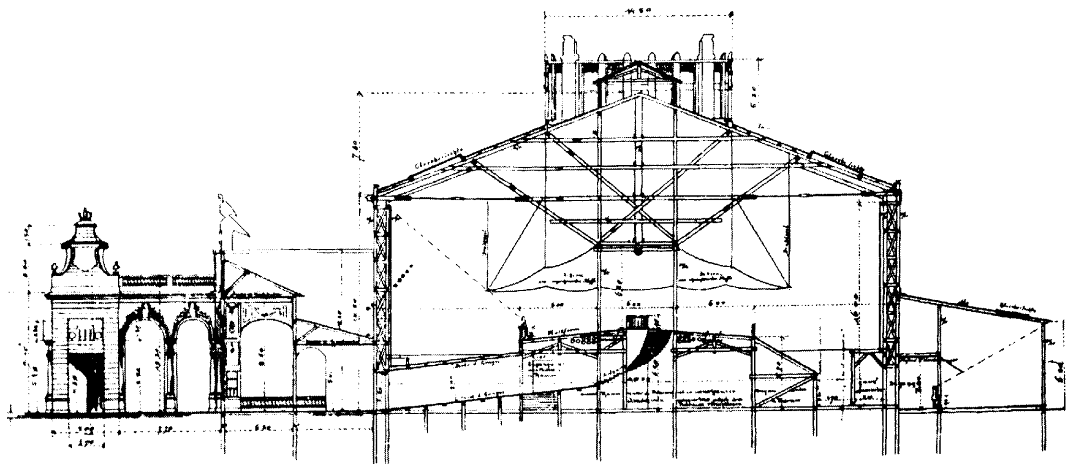
6. From Schaefer 1991, 7.
7. See Stephan Oettermann 1997, 5–7.



*Section of the Panorama Palais in Vienna.* [8]

The first visual mass medium[9], the panorama was a cylindrical exhibition hall dedicated to the display of a continuous canvas painted to represent an exotic location, historic event of famous battle. The public entered through a darkened hallway and up a central stair. Once inside and with the eyes adjusted to the dark, the visitors were treated to a completely controlled spectacular view. In the last half of the eighteenth century the typical panorama

8. From Stephan Oettermann 1997, 307.
9. Oetterman (1997) places the panorama within the same category as moderm mass media, such as television and cinema, as opposed to previous visual media that may have been viewed by many people. The panorama belongs here because of its technical innovation, its sensationalism, and its catering to the new-found leisure time of bourgeois mass audiences.

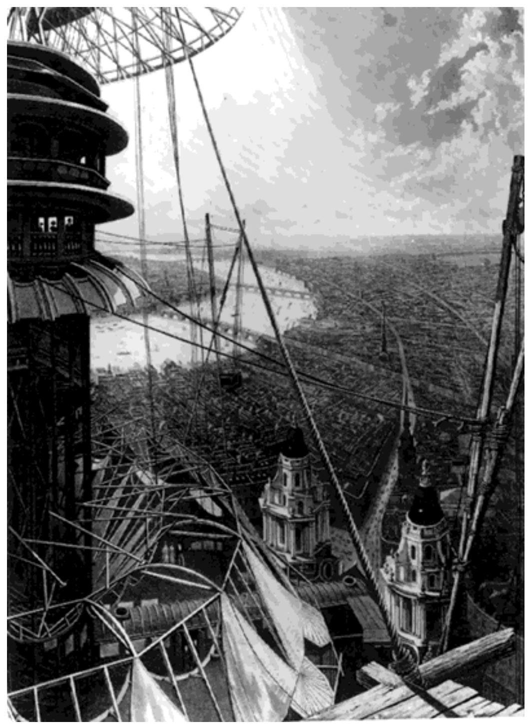
was 50 feet tall and 130 feet in diameter. It housed a canvas with a surface area of 20,000 square feet!

Barker could patent his panorama because of it’s technical innovation: a cylindrical painting spanning 360° with a continuously changing perspective, as opposed to the fixed perspective of a normal image. The variable perspective created an impossible image, outside of the realm of normal views, yet with multiple views allowing the entire public to share the vista. The panorama attempted to free the view—rendering a scene objectively and rationally for the public. At the same time it imprisoned the view—offering an idealized image with the new middle class above it all.

Later developments (myriorama, cosmorama, georama, diorama) added modeled foreground elements, relief, a moving canvas, animated lighting and a changing canvas through the use of transparency. They remained immensely popular public attractions throughout the western world until the end of the eighteenth century, until photography allowed the captured image to be portable and affordable.

*A view inside the Coliseum, London, under construction.* [10]

10. From Stephan Oettermann 1997, 98.



Descendants of the panorama have survived to this day. Projected and photographic panoramas were displayed: the Electric Cyclorama at the 1893 Chicago World's Fair, Thomas Barber's Electrorama and the Lumières' Photorama. More recently we have seen 'Omnimax' and 'Imax' theatre.

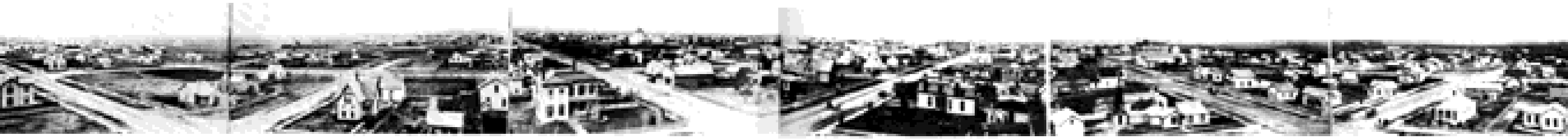
## PANORAMIC PHOTOGRAPHY

Grand Island Nebraska 1885 *by J. R. Moeller. An early documentary panoramic photograph, created by assemblage of smaller views.*[11]

At the end of the eighteenth century photography started to become a popular medium and helped to render the panorama obsolete. Attempts were made to produce panoramic photography by various means from almost the very beginning; William Henry Fox Talbot made the first assemblage panorama from two pictures in 1843. However, the difficulty and expense of piecing together images on one-of-a-kind, hand-developed glass plates made panoramic photography very rare. The first attempt at a true panoramic camera was the Megaskop, a swing-lens camera built by Friedrich von Martens in 1844. The camera had many moving parts and exposed curved glass

11. From Diana Edkins 1977.

plates, and was exceedingly expensive to purchase and operate.[12]



The first practical panoramic cameras were extremely wide fixed-lens cameras available towards the end of the nineteenth century. Kodak and others popularized panoramic photography in the twentieth century with a series of easy-to-use swing-lens cameras.[13] It was also in this period that Rochester Panoramic—later acquired by Kodak—released the famous Cirkut camera. The Cirkut is a rotating-lens camera capable of capturing an image with a full 360° or even greater field of view. Versions were manufactured until the 1940s and antique examples remain a mainstay of panoramic photography to this day.

*Kodak's No. 10 Cirkut Camera.*[14]

12. See Joseph Meehan 1990 14–15.
13. See Diana Edkins 1977.
14. From Joseph Meehan 1990, 15.

*Instructions for operating the*

**No. 10 Cirkut Camera**

THESE instructions are for the No. 10 Cirkut Camera, fitted with the Series II Turner Reich Lens of 10½-, 18- and 24-inch focus, regularly listed.

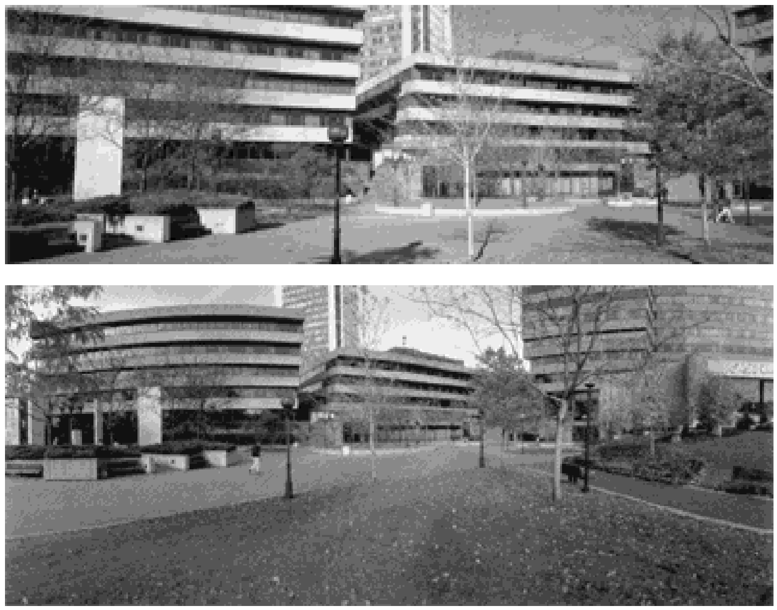
Fig. 1

**Loading the Film Box**

Unscrew the milled head A, Fig. 2, disconnecting the motor from the winding drum. Turn the small winding key B, Fig. 2, until the number 126 appears in the opening. Turn the lower milled head C, Fig. 2, until the white line is opposite number 6. Open the film box by pressing the

1

Different types of panoramic cameras operate according to different principals, and produce images with differing characteristics. The two main categories are fixed-lens cameras which produce a very wide conventional image, exposing a flat film plane through a conventional camera shutter. The various types of swing- and rotating-lens cameras utilize a slit shutter, which scans across a curved film plane. These types of cameras produce an image with a continuously changing perspective like the image in a painted panorama.



*Examples of planar and cylindrical perspective created by a fixed-lens and a rotating-lens panoramic camera, respectively. Photographs taken from the same point of view with a Fuji 617 (top), and a Widelux 1500 . Note how straight lines appear curved in the Widelux photo.*[15]

## PHOTOGRAPHIC VIRTUAL REALITY

In 1995 Eric Chen of Apple Computer presented a paper at SIGGRAPH describing Apple Computer's implementation of image-based virtual reality. Apple pioneered and trademarked their QuickTime VR technology to represent a virtual world using photographic imagery.[16] Since then several other similar systems have become available, but all have the same basic characteristics. Several discrete 3D modeling systems,

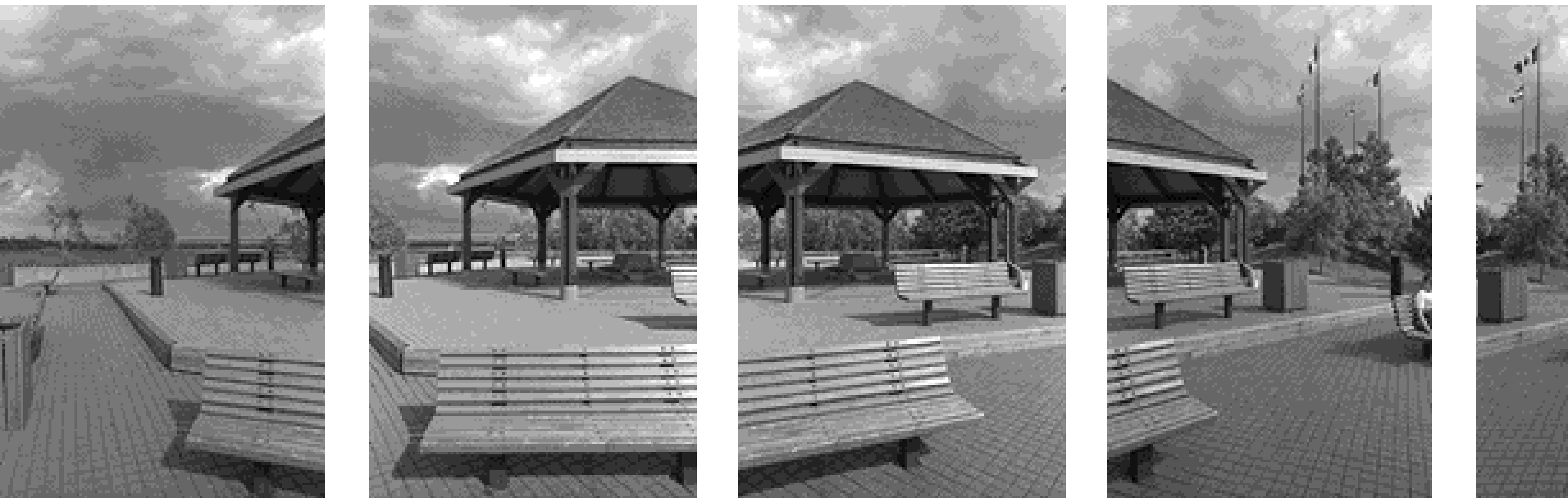
15. From Joseph Meehan 1990, 82–83.
16. See S. E. Chen 1995 for a history of the development or QuickTime VR, and Apple Computer 1998 for information about current software.

such as VRML (virtual reality modeling language) are also beginning to comprise photo VR and photo VR-like capabilities.

QuickTime VR and similar photo VR systems can be used to create panoramic movies, VR 'nodes,' which allow the viewer to look at a photographic representation of a place and virtually turn their head within a 360° field of view. The screen representation is photographically realistic, with changing perspective distortion as the viewer turns. Each node accurately represents the full field-of-view from a particular location. The field of view may also be made larger or smaller, simulating the effect of using a zoom camera lens.

A series of nodes can be linked together into a 'scene,' in which hotspots[17] within the view allow the viewer to jump to another node. A scene with enough nodes spaced sufficiently densely gives a reasonably good sense of walking around from location to location within the site.

17. 'Hotspots' are hyper-linked areas of an image, corresponding with identifiable features in the image.

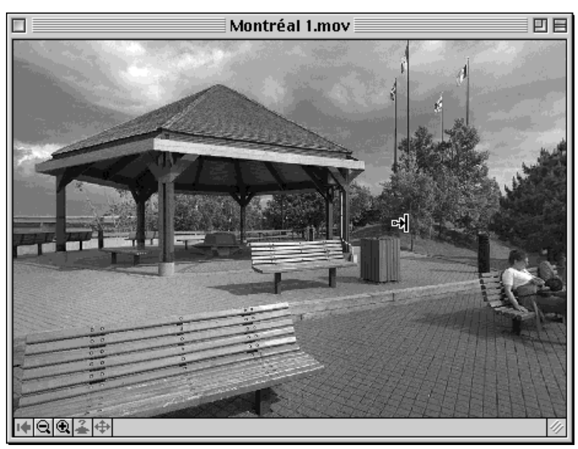


*Several component images that will make up a panorama. These were taken with a 28 mm lens, at 20° intervals, providing 50% overlap between images.*

The VR node, or panoramic movie, contains a raster image of a complete 360° panorama. This is an image with a continuously changing perspective, like that produced by a rotating-lens camera. The VR window on the computer display shows a section of this image, altered to a conventional, fixed perspective by a matrix transformation equation. The perspective correction is performed ‘on the fly,’ so that the viewer can click and drag in the window with the mouse pointer to pan the view. The changing perspective gives a very natural feel of looking around if the VR window is showing a natural field of view (about 60–90°). A narrower field of view gives a tele-photo effect and a wider field of view appears distorted.

*This is a portion of the panoramic image created from the preceding photographs. Notice that the cylindrical perspective curves straight lines.*

The image can be a scanned photo taken with a panoramic camera, but digitally 'stitched' imagery is more common. The photographer takes a series of overlapping, perspective-controlled pictures at intervals from the same point of view. The authoring software is used to warp each image to match part of the panorama's continuously changing perspective. It then overlaps them, finds similarities for precise alignment, and blends the overlapped areas. Perfect imagery can be stitched unsupervised, but usually some manual intervention is required for best results.




*This is the VR panorama window. The perspective resembles that in one of the original photographs, but changes continuously as the view is panned right and left.*

The authoring software also allows creation of the panoramic movie and lets the developer edit hotspots in a graphical environment.

The author then defines the screen dimensions and default field-of-view of the finished VR 'movie.' Some combinations appear much more natural than others. A larger window is usually preferable, more nearly filling the viewer's field-of-view, or at least field of attention. A field-of-view (or zoom factor) that is too narrow reduces the effect of depth from the rotating perspective, and one that is too wide looks unnaturally distorted. There is no 'correct' field-of-view objectively corresponding to our own. The choice of VR perspective is a projection much like a map perspective: a trade off between demonstrating particular aspects of the subject and most resembling a 'natural' view.[18]

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18. There are other implications of the VR's identity as a 'projection' of the real world which result from the way the image was captured.

    *. . . almost all—99.9 percent—types of modern photography uses the shutter method of creating a picture. In this method, the shutter, which is ordinarily in a closed position, opens to allow light to fall onto the image plane for an instant in time. This length of time is called* delta T*. The film remains stationary relative to the lens during this process. The resulting picture contains the height and length of a subject exposed within a particular delta T from a single perspective in space with a single vanishing point. This two-dimensional view of the world is widely accepted. But the world is actually multidimensional. Just think about it: everything is happening everywhere all at*

The nature of the VR as a projection of three-dimensional space is a very important concept in defining it as a representation of landscape. On the one hand, being one of many possible projections of real space, it cannot be stated to be the 'true' picture of the world. On

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*once from every possible angle and point of view. Furthermore, all of this is happening along a stream of time.*

*Using the* slit-scan method, *on the other hand, you can create a picture with the same camera, but the approach is fundamentally different. With this method, an image is recorded on a moving piece of film as it is being exposed through a slit. No shutter opens and closes during the exposure. Because there are no frames, the resulting picture is seamless and continuous in time. There is no opening and closing of a shutter. What you get is a representation of the action in the scene as "seen" through a thin slit by the moving piece of film. The slit, then, forms and "event horizon." Perhaps most important, the final image contains an enormous number of perspectives, the product of the scanning motion.*

*As a result of the film's continuous motion, a secondary focus that isn't associated with the lens exists. This perfect focus, called* synchronization*, is the image clarity created when the speed of the moving film matches the apparent speed of the subject. Of course, synchronization doesn't always take place. If the film motion is faster than that of the subject, the subject is elongated. Conversely, if the film motion is slower than that of the subject, the subject is compressed. Keep in mind, however, that not all lenses are designed the same way, and that it is impossible to synchronize all speeds present in a scene when using a single depth of focus. . . .*

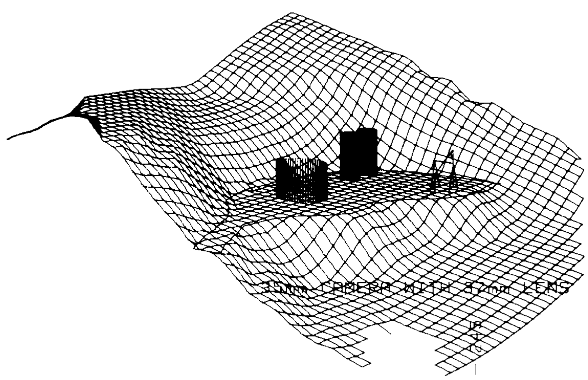
From Ron Globus and Rick Globus, "The slit-scan method" in Joseph Meehan 1990.

From this the stitched-segment production method used in most photographic VR work is inferred to be segmented in time, as well as in projected space.

the other hand, as a geometrically and temporally precisely defined projection, it must be considered real objective data about the landscape, as much as any cartographic information; all the more so because it is data captured from the real environment and not an artificial abstraction.

There are several commercial technologies available to accomplish these goals. Apple's QuickTime VR was chosen for the project because of its maturity, wide distribution of the playback software and integration with other multi-media data types.

*Three-dimensional landscape computer graphics depend on large numbers of data points for their realistic appearance. This creates a huge burden on even the most powerful processors.*[19]



19. From Burrough 1986, 47.

## CAPTURED IMAGE VS. CARTESIAN CONSTRUCT

Recently there has been much research into development of more advanced graphics and visualization systems in landscape design and GIS. This has been largely an outgrowth of cartographic, computer-aided design (CAD) and 3D modeling systems.

> *. . . the main thrust of computer graphics has been towards making the display screen into a window through which one beholds a virtual world. This inspired a programme of research towards the simulation of realism through concepts and procedures for geometric modeling of 3D objects and scenes. These include hidden-surface removal, surface texturing, lighting, movement, volume visualization and virtual worlds.*[20]

Three-dimensional computer modeling is a direct extension of CAD and vector graphics principals into the third dimension. Vector graphics are mapped in a 3D coordinate system. 3D models can be texture-mapped with scanned or derived images for a more realistic look, or to visualize map data. Interactive animation is added to create a complete interface using a ‘natural-scene’ paradigm.

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20. See M. Visvalingam 1994, 18–25.

*The most sophisticated Cartesian representations of landscape are currently found in computer games.*[21]

This type of 3D modeled virtual reality is well developed in industrial and entertainment applications. Flexible photo-realistic rendering software and powerful special-purpose 3D display hardware is available. However there are two big stumbling blocks for using 3D modeling in landscape-scale visualization.

The first problem with using 3D modeling in GIS is the sheer complexity of a realistic landscape scene. To create a natural-looking scene at the landscape scale requires an exceedingly detailed and complex model. As scale decreases, scene complexity increases, and the amount of data in such a model goes up geometrically. Modeling systems which use a deterministic model with a discrete data set will overwhelm the most powerful hardware and overfill the biggest storage systems. Creating the data set

21. Screen shot from “Myth II: Soulblighter” [computer game], see Bungie 1998.

requires huge amounts of skilled labour. ‘Stochastic’ modeling systems, which use random numbers to create naturalistic scenes by summarizing broad data sets, decrease the load, but they don’t create a true representation of the environment, merely an abstraction.

The second problem is that even in the best case, a 3D model is an abstraction or a reconstruction of the real world, not a description of it.

Remember that in a GIS, according to Burrough, “Geographical data describe objects from the *real world*. . . .” A hand-made CAD-based construct may be our best approximation of objects in the real world, but this technique is far better suited for prescriptive modeling rather than descriptive: our intentions or designs, rather than a representation of the existing world. 3D modeling is good for building designs but not for real landscapes.[22]

The captured image, on the other hand, is perfectly suited to realistically representing existing landscapes, with all of their subtleties intact. The ruins of an old monastery, with crumbling walls and snow drifting in the

22. This discussion refers to types of virtual environments, but does not include other representations in the realm of visualization science (ViSC). ViSC includes other types of visualization which may be more appropriate abstractions representing other kinds of data, or at smaller scales than is a VR representation. For a discussion see Hilary M. Hearnshaw and David J. Unwin 1994.

corners are instantly captured with a snapshot or clip of video. The appearance of the surrounding fields halfway through harvest time cannot be adequately modeled with a 3D software package. These are the resources that landscape architects and planners must be able to manage.

## VIRTUAL REALITY IN GEOGRAPHIC INFORMATION SYSTEMS

> *Geographical information systems differ from computer graphics because the latter are largely concerned with the display and manipulation of visible material. Computer graphics systems do not pay much attention to the non-graphic attributes that the visible entities might or might not have, and which might be useful data for analysis. Good computer graphics are essential for a modern geographical information system but a graphics package is by itself not sufficient for performing the tasks expected, nor are such drawing packages necessarily a good basis for developing such a system.*[23]

Burrough, coming from a background of soil resources survey, does not fully address the “realm of attributes useful for analysis” in diverse areas of study including landscape architecture. Assuming that, by ‘graphics,’ he

23. See P. A. Burrough 1986, 8.

means map or computer display attributes as signifiers of landscape attributes, and not representative of the landscape itself. However when we include virtual reality, in a landscape architecture application, the distinction between graphics, interface and useful data must be more precisely defined.

Although landscape architects and other members of ‘soft’ professions were instrumental in the early development of GIS[24], the focus of GIS development began and has remained primarily on a cartographic model of the landscape. The extensive adoption, and necessarily most of the development, of GIS by engineers has maintained this focus.

The well-accepted definition of GIS from chapter 1 is practically always restated including the term *spatial* to describe the nature of data in a GIS, in reference to the cartographic representational model. However, as we have seen in many types of immersive imagery there are other ways to represent spatial relationships than maps.

The definition of GIS is also often explicitly extended to include “systems designed primarily to capture spatial information and also to process it, namely remote sensing

24. See J. G. Fabos and S. J. Caswell 1977, D. E. Sheehan 1979, and C. Steinitz and H. J. Brown 1981. The non-digital roots of information systems for regional landscape planning are revealed in Ian L. McHarg, 1969.

systems."[25] This definition includes more than just remote sensing! The VR photographer uses a system which captures and processes spatial information (related to visual qualities and relationships).

Referring back to Burrough's definition, VR can be integrated into all three descriptive aspects of GIS. Data describe objects in terms of:

> *(a) their position with respect to a known coordinate system, . . .*

A panoramic VR node is a precisely defined projection of a view (or the set of views) from a unique location. Future technological developments will relax this requirement for focalization, as we will see. Furthermore, it embodies the qualities of map graphics in that it shows objects in a known coordinate system (with the added layer of classical perspective superimposed on the geographic coordinates).

> *(b) their attributes that are unrelated to position (such as colour, cost, pH, incidence of disease, etc.) and . . .*

The image in a panoramic VR node describes the colour, texture, shape, etc. of objects within the view. The

25. See R. H. Haines-Young, David R. Green, and Steven Cousins 1993, Introduction.

image may also include annotations, symbols, drawings, projections of vector GIS data, and other visual information relating to objects within the view. The representation of non-positional attributes is a characteristic of database records, however VR imagery has visual attributes that cannot be captured in a text or numerical field.

The VR representation conveys more information than traditional cartographic abstractions in two ways. The first is that through contextualization and relating data to visually recognizable features, it allows the viewer to immediately grasp the scale, orientation and relation of objects and data represented in the view.

The second advantage of the VR representation is more difficult to define. The ability to view data through multiple realistic views adds a gestalt perception of the landscape that is not possible through cartographic abstractions. For example, it may take volumes of tables, charts, maps and textual information to give one a thorough understanding of the drainage system on a particular site. On the other hand, navigating a single VR view may provide more intuitive understanding of most of the same factors.

> *(c) their spatial interrelations with each other (topological relations), which describe how they are linked together or how one can travel between them.*

The relationship between VR nodes and other data in the GIS can model the interrelations of the objects they represent. Hotspots within the node point to various kinds of data. They can move the point-of-view to other locations, simulating a move within the site. They can link to other kinds of data items: database records, statistics, maps, attached documents. They can prompt lookups, searches, analytical operations, display of derived data or other types of database operations. A hotspot has a direction within the VR, and it has a destination. Thus it embodies the characteristics of both geographic (map graphic) topology as well as relational database topology. The interactive nature of photographic VR adds a vector to the GIS which crosses the boundaries between graphics and relations.

The relationship described by each hotspot's action is itself a record within the database. Therefore, the landscape interrelationships represented in the VR view respond to the changing state of the land data. The VR landscape is potentially as fluid as the data itself.

Finally, as the GIS user's on-screen pointer passes over the hotspots in a VR view, the pointer graphic changes to display the type of relation the individual hotspot triggers. This provides real time visual feedback, revealing the interrelations embedded in the image and helping to render transparent the depth of the database.

Photographic VR may be classified into a new category among the aspects of GIS, not just another data type. It encapsulates and reveals the position, attributes and interrelations of objects in the database, integrating both the content and form of the GIS.

## POTENTIAL DEVELOPMENTS

As photographic VR technologies mature, they begin to support other types of media capabilities, linkages and interactivity. Off-the-shelf technology is coming into the market which allows embedding ambient sound, directional stereo sound, animation and video into panoramic VR. 3D CAD-type models and vector graphic overlays can be embedded with precision into a VR node. These developments are creating new potentials beyond the scope of this project for more realistic and captivating representation of the landscape, more dynamic and diverse data types, and a wider range of representational, analytic and prescriptive activities within the VR GIS.

*An example of a QuickTime VR node with embedded three-dimensional Cartesian models. The cabins are rendered in real time, and can be moved interactively within the perspective of scene.*[26]


During the same SIGGRAPH conference where Eric Chen presented Apple's work in QuickTime VR, Leonard McMillan and Gary Bishop of UNC presented a paper titled "Plenoptic modeling: an image-based rendering system." The researchers at UNC are exploring the theoretical limits of image-based rendering. Plenoptic modeling is a mathematical technique which takes photographs taken from several points of view in a scene, and creates new images simulating views from other, un-photographed vantage points. This is not a 'reconstruction' technique, which builds a 3D computer model from multiple photographs, but simply a way of creating new images.[27]

26. See Bill Meikle 1998 for VRScript, a complete authoring environment which integrates visual effects, sound, 3D models and interactivity into QuickTime VR.
27. See Leonard McMillan and Gary Bishop 1995, and Jan Kautz 1998.

New techniques such as this one, combined with powerful desktop computers of the near future, promise to extend photo-based VR into a continuously navigable environment, with rendering speeds that are independent of scene complexity.

# INTEGRATING PHOTOGRAPHIC VR INTO THE LANDSCAPE DATABASE

## THE IMAGE OF A LANDSCAPE

Creating VR imagery is done in two main stages. The first is image capture and processing, which involves scanning or otherwise digitizing imagery and using it to create the panoramic image. The second, 'authoring' step, is the creation of VR movies and their embedded links.

### CAPTURING IMAGERY

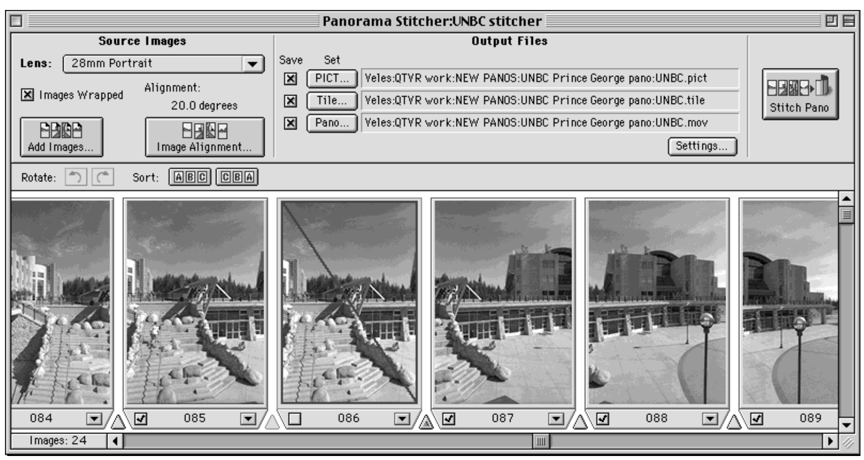
For best results, imagery for a VR panoramic node must be captured with great precision. All image segments should be photographed from precisely the same point of view, to avoid mis-registration and parallax error. For scenes which contain objects near the camera, this means using a specialized support which rotates the camera around the nodal point of its lens.

*A panoramic tripod head has precise markings that allow a photographer to rotate and shoot pictures at precise angles. The mounting bracket displaces the camera back and to the side, so that the nodal point of the lens is over the axis of rotation.* [28]

28. From Kaidan Inc. 1998. This is the same rig used to capture imagery for this project.

The image segments should be photographed at regular intervals, allowing for greater than 50% overlap of images. And the image segments must be photographed with the camera perfectly level, to avoid vertical perspective, or ‘key-stoning’ in adjacent images. Because of this requirement, photography is usually done with the camera in portrait aspect, to capture the maximum vertical field-of-view.

*Segments of the panorama are assembled in the ‘stitcher’ window.*




There are several vendors offering tripod rigs for VR photography,[29] and instructions for construction of such are rig from inexpensive hardware store parts can be found on the Internet.[30]

29. Availability from Kaidan Inc. 1998, Peace River Studios 1998, Be Here Inc. 1998, and Gruppo Manfrotto 1998.
30. See Concepts In Motion 1997.

Photography must be digitized—either captured with a digital camera and transferred to a computer, scanned from film or photographic prints, or digitized from video using a video capture card.

*The individual images do not fit together—each is a projection on a different picture plane.*

*A complex matrix equation wraps each image around the same cylindrical projection.*

Once in the computer, the images are warped to correspond to the continuously changing perspective of the panoramic image. The image warping is accomplished using a geometric matrix transformation, based on the field-of-view of each image which is determined by the camera lens' focal length.

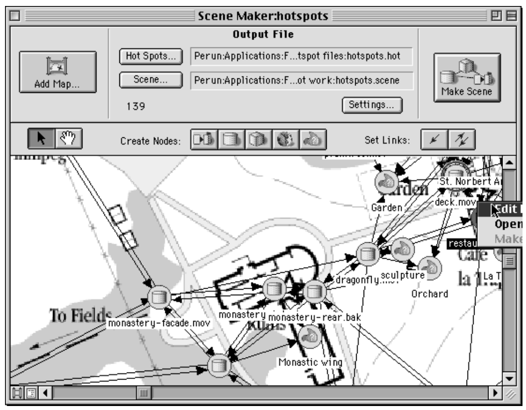
*Finally a search for similar pixels finds the best correlation to blend them together.*

The warped images are overlapped and blended together to create a continuous panorama. Most authoring software uses a search and correlation function, to find the most accurate image alignment automatically. Often manual tweaking of the image parameters by the operator is necessary, but good quality imagery can often be 'stitched' without intervention.

## ASSEMBLING THE VISUAL DATA

Once a panoramic image is available, it can be re-sized, compressed and encapsulated into a new VR movie file. Where file size will be at a premium due to limited storage or the need for transmission over a slow network, image data is compressed using one of several schemes.[31]

*The list of hotspots for all panoramic nodes is created by dragging the VR files into a map window, and dragging links between them.*




Hotspots are drawn manually, superimposed over the panoramic image in an interactive graphic environment. Each hotspot is assigned an index number which will later be used to identify it. Playback parameters, such as window size, default field-of-view and starting view direction are chosen, and the software saves a VR movie file.

31. For efficient storage and transmission the image data in VR scenes is compressed using one of various software *codecs* (coder/decoder). A codec implements a particular compression algorithm which may be optimized for best image quality, for fast decompression and smooth playback, or for smallest compressed file size. For detailed information see Terran Interactive 1998.

*Hotspots are drawn interactively on the panoramic image. Each hotspot is designated by an index number, and a text field which will appear in the VR controller, to provide feedback to the viewer.*


The movie file can be played back on any computer with appropriate software installed. In the case of the QuickTime VR technology chosen here, the software is already available on 23.9 million windows PC computers, or 67% of the installed base.[32]

## CREATING A LANDSCAPE DATABASE

The site surrounding St. Norbert Arts and Cultural Centre and ruins of the former Trappist monastery Notre Dame des Prairies was chosen as the sample set of data. It's a compact site with various mapped and visual resources, a rich history, and a modest archive of textual and photographic materials pertaining to the site.

32. See MediaMetrix 1998.

The landscape database was created on Macintosh computers using Filemaker Pro software.

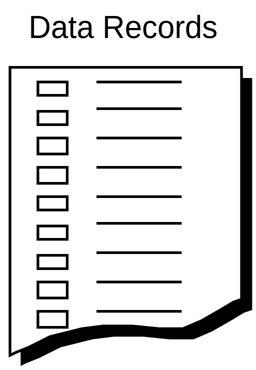
## THE RELATIONAL DATABASE

The database consists of three flat-file databases, or tables.

The first table is a simple database of information records pertaining to the site. Each record has a field containing unique serial number and fields containing information about the item, or *metadata*. Metadata in this database include the record's name, the type(s) of data it contains, source of the data, copyright information and keywords which can be used to search and relate records. Each record can contain one or more kinds of data: a container field that may hold image, video or sound, a text field, an Internet address and a path to an external file.

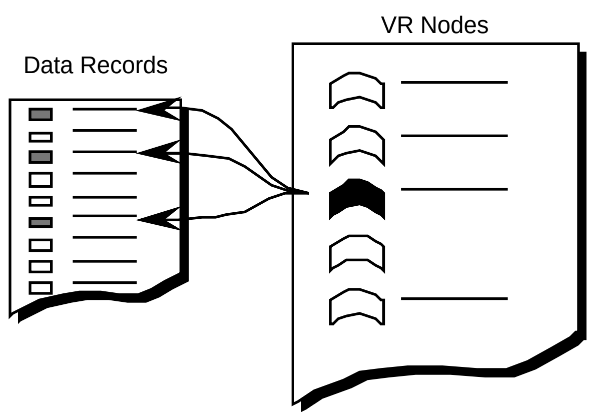
Having this table allows one to perform keyword searches and browse the resulting sets of data items. Searching for the keyword 'monastery,' for example, yields a set of modern and historic photographs which include the monastery or its ruins, and text items describing the building and episodes from its history.

*A 'table' in a relational database is simply a list of records, each with several fields containing data.*




The second table is a similar database, but it manages the VR nodes which are used to navigate the site. Each record in the 'nodes' table has similar metadata fields to the 'data' table. It also has fields specific to the VR files: precise coordinates that the view was created at, a copy of the panoramic image used to create the view and a path name to the VR movie file itself.

*Each VR node in the second table has a keyword-based relationship to one or more data records. This is a relational database.*

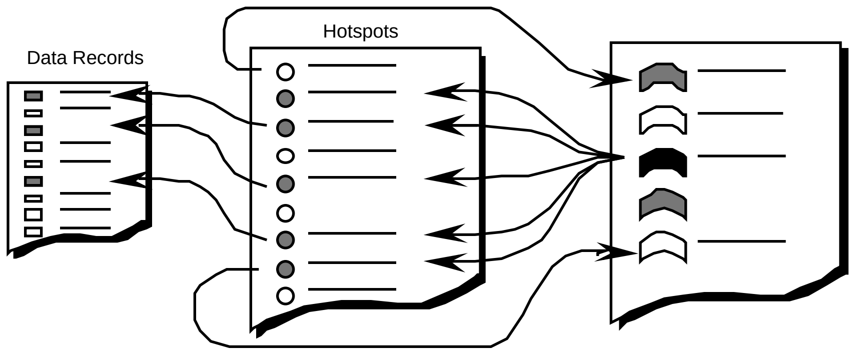



Using the keywords field, a relation is created between the 'data' table and the 'nodes' table. While viewing the record for a node, one can directly browse all of the related data records in a scrolling list containing the data record's name and any picture it contains. The list of related records is a live link, allowing direct editing of the related data and changing as items are changed, added and deleted.

With these two straight-forward tables and a simple relation we have created a slightly more complex web of relations and, incidentally, a geographic information system containing coordinate position, attribute and interrelation information.

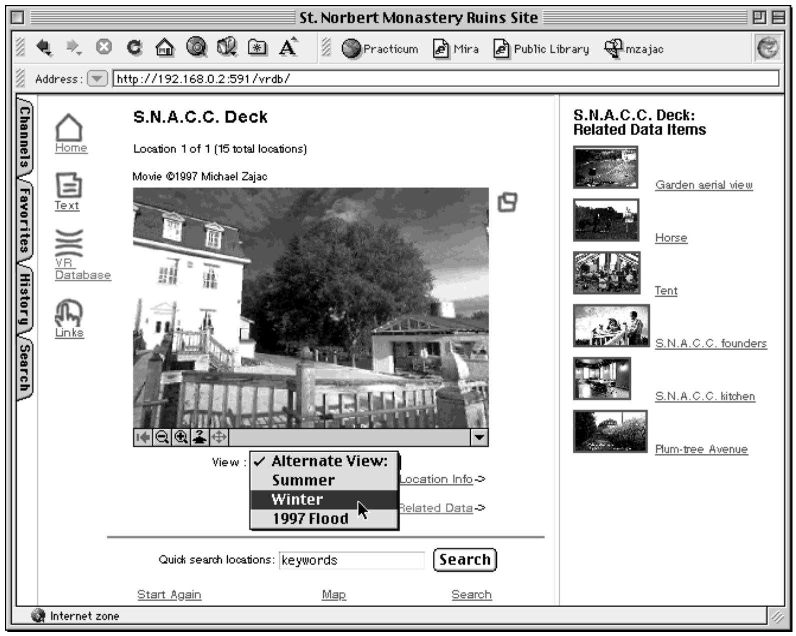
The third table is a list of hotspots in all of the VR nodes. The 'hotspots' table establishes another layer of interrelations within the database. For each of the hotspots which has been created in any of the nodes there is one data record. The record contains a unique serial number to identify each hotspot, a field containing the serial number of the node that the hotspot is found within, and an index number which ties the hotspot record to the individual hotspot in the node. The hotspot table also contains information about the target of the hotspot: whether it is another node record, an individual data record or a search of the database. Finally, the hotspot records store the position to which a destination node must be rotated, completing the vector and maintaining a natural 'walk-around' feel in the VR.

*To help manage the complexity of so many relations, a third table stores data and destination of each hotspot in each VR node.*




Keeping the hotspots in a separate table makes this database completely flexible. Using the normal database editing tools and automated functions, one can manage not only the data, but also the visual relationships between them. Adding new nodes and recreating the web of links between them is simple, accomplished with one consistent interface, and capable of responding to changes in the database.

*The web interface for the landscape database. The viewer is selecting a different version of the same view. On the right is a list of related image files.*

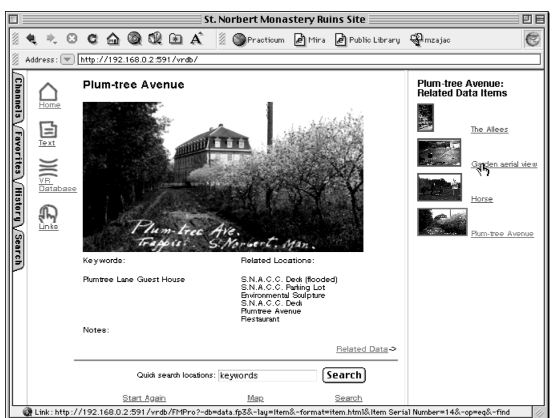



## THE DATABASE ON THE WEB

Pages of information on the World Wide Web are created using Hyper-Text Markup Language (HTML). The text-based HTML language consists of tags which describe the structure of a page layout, and contains pointers to graphics, movies and other embedded objects which will appear on the page.

Filemaker Pro has the built-in capability to serve data over the WWW, substituting data into HTML templates before sending the resulting pages to the client web browser. The web pages are created dynamically, on-the-fly, in response to requests by the browser. This is a very powerful way of creating a web site. The standard form of each page can be created once by the web author or graphic designer, and an unlimited number of data pages served over the Internet. A standard HTML template need only be changed once, to change the appearance of an entire site.

This dynamic creation of data pages also has the benefit of immediate access to data in the database. As database items are changed, web browsers using the database always see up to date information. To check if a record or the results of a search have changed, one need merely press the web browser's 'refresh' button.

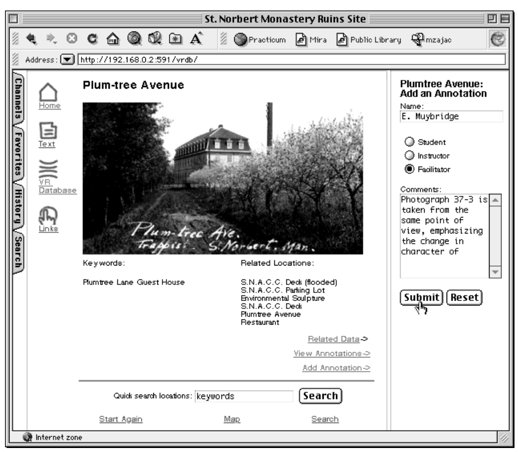



*One of the image records has been selected and appears in the main part of the window. A new list of records related to this one is now visible on the right.*

## THE WEB INTERFACE

The presentation of the database on the web page reflects the structure of the database, using familiar web site conventions. A site index, embedded graphics and movies, hyper-text links and search forms are all self-evident in their function. To help make clear the relationship of the data, the web page is divided into two frames. The left-hand frame displays a main database item; a VR node or contents of a data record. The right-hand frame displays the list of results of a search, or a summary of incidental information about a data record. Both frames have links which can load new information into itself or the other frame.

*The viewer is filling in the blanks to add a comment to one of the data records.*




To the casual user, this appears to be a straight-forward web site. On the left one can navigate the site visually, by dragging and clicking in the VR window. Other buttons load related data into the companion frame, responding to the relation from the node without hiding it and losing the relationship with the site.

# CHARACTERISTICS AND ADVANTAGES

## LANDSCAPE DOCUMENTATION

Photographic virtual reality integrated into a landscape database provides a rich environment for documenting a landscape. In addition to usual GIS data types, including multi-media such as image, sound and video, the database presents an easily comprehensible representation of the site integrated with an intuitive way to navigate. This interface helps to orient map-based representations of the site, it locates objects on the site and provides a strong sense of the visual quality of the site.

## TRADITIONAL RELATIONAL DATABASE POWER

The relational database engine behind the photo VR database is the same kind that manages data in a traditional GIS. It is a scalable database engine which is suited to expanding a database to a very large data set, and it is capable of storing and accessing data in external, industrial-strength databases.

All normal capabilities are available. Additionally, the interface, which allows database queries and navigation through the VR window, makes evident visual and geographic relations within the database that would otherwise be obscure.

## EASE OF USE

Traditional navigation, search and editing tools are provided as standard web site elements which are un-intimidating for the casual computer user. The web framework provides a familiar 'point and click' visual metaphor for most interface elements. It is easily extensible to provide for file storage and new media types (e.g. video, sound, animation, interactive white-board). It can be implemented on any web server platform (UNIX, MacOS, Windows NT, etc.) and is scalable for any database size.

## INTERNET ACCESSIBILITY

The database is served over a TCP/IP (Internet) connection and requires any standard web browser as a client.

Navigating , searching, altering records, adding data and even re-structuring the links to and from the VR imagery in the database can all be done through the web interface. Security features are built in. The ability to alter the structure of the site navigation has particular potential to design novel, dynamic databases.

The database application itself can be administered, altered and re-designed by an administrator at the local computer or over a network connection, while remaining available to clients.

## APPLICABILITY

### LANDSCAPE PRESENTATION

The photo VR database incorporates a traditional GIS, enhanced with a novel and attractive VR representation, presented with an easy-to use web interface.

These characteristics make it a well-suited tool for promotion, education and public presentation of planning proposals.

### PROFESSIONAL COLLABORATION

All the functions of the relational database are available for any user on the network. Password access is available to ensure security or limit access to data.

With the addition of free file transfer server software, any type of computer file can be attached to any record in the database, including text, scanned drawings and CAD drawings. Shared resources can be associated to geographic locations on the site.

The contents of the database can be collaboratively maintained and enlarged. During a long-term project the visual development of a site can be monitored by members of the team who don't have direct access to the site.

Media support in the QuickTime VR technology can be used by technically advanced users to place sketches, photos, video and 3D models directly into the VR imagery. Visualizations can be shared and integrated in the representation of the site.

## COMMUNITY AND CLIENT PARTICIPATION

The database can be used to gather comments and suggestions, and to conduct surveys through web-based forms. Planning and design proposals can be visualized and presented to the public for feedback.

Different levels of access can be used to allow the public to browse parts of the database while a collaborative project is in progress. The public can have direct access to timely information on the project, with no danger of accidental or intentional data loss.

Annotation of records in the database, or public contribution to the content is possible. Collaboration could be extended to include the schools, constituents or the public at large in the information gathering and decision making processes. Since some of the available VR authoring tools can be automated, it is even possible to have participants submit the segments of a panoramic image to create new VR nodes without the intervention of a multi-media expert. Ultimately, a database could be built by members of the public to create a community-owned resource.

## CONCLUSION

The tight integration of photographic virtual reality and a World Wide Web interface add several new dimensions to a landscape GIS. A realistic representation of the landscape encapsulates visual attributes for designers, and it also improves the integration of data and makes the database easier to use.

These benefits are gained without greatly increasing the resources required to implement the GIS.

A demonstration project was realized which makes a representation of the St. Norbert Arts and Cultural Centre site accessible to the public, providing interpretive text about the site and a searchable database of relevant historic photography. The result is a public resource, with a depth of information about a public landscape which was previously unavailable.

Many of the potentials of applying these technologies have only been touched upon in this paper.

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