Abstract
The characteristics of the traditional map have remained unchanged for centuries. A symbolic representation of reality, the map relies on the user's understanding of scale, orientation, reference, and location.

With recent developments in the field of Information Technology (IT) and the Internet, in particular Urban Information Systems (UIS), the effectiveness of the traditional map is becoming limited. Paper-based maps are evolving into interactive multimedia systems, adding dynamic intelligence to a static medium. Computer designed 3D models now allow the user to "get inside" the map, exploring it in an intuitive, natural manner, becoming familiar with the virtual in much the same way he/she becomes familiar with the real.

This paper focuses on the design theory behind 'the Glasgow Directory', a fully interactive, virtual UIS developed by ABACUS (Architecture and Building Aids Computer Unit Strathclyde) for the purpose of promoting the city of Glasgow to both the local and tourist sectors. It will show how dimensions, directions and marketing opportunities are now available for any cyber-city on the Internet.

1. Introduction
Since the dawn of time, humanity has endeavoured to comprehend its environment, providing knowledge and reassurance of a safe existence. Nowhere is this more true than in today's modern cities, where, often on foot, one's vulnerability is greater than ever, especially if in an unfamiliar city.

At best, disorientation within a city results in a loss of time or missed appointments. At worst, it can result in true fear of the unknown, being a victim of crime, or the development of a negative long-term attitude towards that particular city.

2. Traditional Maps
To date, traditional 2D maps have been the common answer to navigating the city, presenting the user with an abstract representation of their current location. The symbolic metaphors used in the maps allow for a reduction of information to a size which is considered manageable, so that the map can be easily read.

Although a clear indicator of street names and possible transport locations, such a map gives information as to the 'feeling' of an area. The map describes space, not place. It seeks only partially inform, and not at all to educate or entertain.

Maps however have not always been designed in this way. During the medieval period (16th century) many urban maps were designed not only to provide a plan view of the street layout, but also show the geometric form and visual appearance of the actual buildings themselves.
These aerial views often sacrificed accuracy in order to ensure that all the finest buildings monuments were shown, and the artistic qualities of the work were as important as its object status. Although often difficult to read, such highly detailed maps gave an insight into the nature and feeling found within the described location.

The Renaissance brought with it improved surveying skills, allowing the city to be accurately measured and displayed as a plan. Together with the emerging needs of the military and transaction records, by the mid 18th C, these new 'plan' maps had almost replaced the aerial view and since the late 19th C introduction of lithographic printing, the basic 2D map has indeed become the norm in city representation.

3. Navigating the Virtual World

It could be considered that when reading a 2D map, the user has entered a virtual environment in its most basic form. The degree to which the user understands this environment is dependent on very basic factors that he/she uses to understand and navigate in the real location.

The human brain relies on its cognitive mapping ability to understand the world around us. These maps are stored in our memory as mental images, as propositions (facts) or as both. When navigating in an unknown environment, the use of cognitive maps is limited since these maps are the result of having previous experience of that specific situation. Instead, we rely on our memory and experience of previously visited environments of a similar nature. Such images

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necessary if an individual is to operate successfully within an environment and to co-operate with her fellows\(^5\).

It is vital therefore, if we are to develop a legible and memorable virtual environment that describes the 'feeling' of an area, firstly to identify and understand the unique spatial elements (images) that make up the city itself.

4. Why 3D?
The world we live in is not flat, so any realistic representation of it must also include the dimension. It is more natural and intuitive to navigate in 3D than 2D because of the way in which the brain deals with the acquisition of spatial knowledge.

Spatial knowledge is understood to consist of three indistinguishable components, all of which for the stages in the knowledge acquisition process\(^6\):
- landmark knowledge
- route knowledge
- configurations or survey representations of the environment

4.1 Landmarks
Lynch defines landmarks as a type of point-reference, usually a simply defined physical object, building, sign, store, or mountain. Their use involves the singling out of one element from a host possibilities. Some landmarks are distant ones, typically seen from many angles and distances, or the tops of smaller elements and used as radial references\(^7\).

In 2D maps, landmark definition is almost impossible. At best, obvious landmarks are represented in a different colour on the plan and with bold descriptive text. It must also be remembered that what is considered a landmark differs greatly depending on the individual.

![Figure 2. Urban landmark representation in 2D and 3D](image)

4.2 Routes
Routes are considered the second stage of spatial acquisition and are used to connect the previously mentioned landmarks together. Lynch describes routes (paths) as channels along which an observer moves. They may be streets, walkways, transit lines, canals or railroads. For most people, these are the predominant elements in their image of the city. People observe the city as they move through it, and along these paths the other elements are arranged and related\(^8\).

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Although more easily identified than landmarks, the representation of any particular route on a 2D map will struggle to provide the realism of the physical location. What looks like a easy stroll from the park to the shopping centre, may turn out to be akin to mountaineering or rock-climbing! Without an understanding of contours (which rarely exist on urban maps), such facts often go unnoticed by the user resulting in confusion and disappointment.

4.3 Configurations
Configuration or survey knowledge is the final stage in spatial acquisition, and involves the construction of interrelationships between Landmarks, Routes, and everything in between, based on location, proximity and direction.

Such configurations could be likened to Lynch’s districts, in which the observer, (unlike landmark and routes, which are experienced directly) mentally enters “inside of”, and are recognisable as having some common, identifying character. Districts are often dependent on a personal selection of elements, and are therefore difficult to create from a 2D map in which information is limited to the medium.

The benefits of 3D are obvious: the 3D content that is currently being developed is not like a 3D movie, it is an interactive experience. You move around objects and explore spaces on your own. You take however long you want to examine an object, or in this case wander around in a “world” until it’s image is clear and legible. The viewpoint belongs to the viewer, not the author of the content. A traditional map presents one point of view – the plan, with no ability to “get inside” Take for example a training video in how to assemble a part. You may want to run one panel of tape over and over, but in 3D you assemble the part yourself, take it apart and put it back together until you are comfortable with it.

Utilising the power of recent advances in computer-aided three-dimensional modelling, it is no possible to build new-generation interactive 3D maps which can be both accurate in plan as well as truly representing the ‘feeling’ of a city. Preserving the accuracy of an original survey, such models also represent land and building form realistically. Extra detail can be given to buildings of interest to reinforce their ‘landmark’ status. If you can’t see or understand something from one angle, you simply ‘walk’ around it to change your viewing angle. Unlike before, we can at last get “inside the map”.

5. Summary of Key Technologies
Three dimensional modelling of the built environment on the World Wide Web (WWW) may broady be divided into two categories:

• The 3D Model – predominantly developed using Virtual Reality Modelling Language (VRML).
• The Navigable Movie – a number of development platforms, of which Quicktime Virtual Reality (QTVR) has the largest user base.

5.1 VRML 2.0
VRML is a specification for defining 3-D environments (worlds) on the Web. Although it is not an extension to HTML, it is similar in many ways. Like HTML, VRML is a platform-independent document-centred ASCII language. Unlike HTML, it tells the computer how to create 3-D worlds constructing complex geometry including polygons and solids. VRML however is more than just another geometry: users, or “avatars” are able to explore a model, viewing it from any angle of their choice.

With the recent introduction of VRML 2, developers have full control over light sources, objects...

materials, and special effects such as fog. One of the most important advancements incorporated in its second release is its ability to support other languages. It is this new addition that removes the static worlds of VRML, allowing user interaction, animation, and the ability to manipulate VRML data externally.

VRML is available to anyone with an Internet browser. The 'plug-in' viewing software is freely available to download from a selection of companies, of which Cosmoplayer from Silicon Graphics is by far the most popular. The development of a VRML world is becoming increasingly easier with many commercial CAD packages such as FormZ and 3D studio Max, exporting directly to the VRML format. Existing models can be easily converted, as was done with the geometry for the 'Glasgow Directory'.

5.2 QTVR

QTVR can be considered a hybrid between virtual reality and digital photography. Realism is achieved through photographic, video, or computer renderings, which allow the user to pan round the captured area or node. Although highly realistic representations are possible, navigation within any one node is limited due to the users viewpoint being fixed to the original location of the camera. The ability therefore to walk around as one may do within a VRML scene is not so apparent however by linking nodes, the user can 'jump' between them, creating a sense of movement.

The capture of a QTVR scene typically involves a photographer shooting a series of photos using a 35mm camera with a 15mm lens. With the focal point of the camera lens precisely located over the tripod's rotation axle, the camera is turned 30 degrees after each exposure, resulting in a constant width of overlap between pictures. The images are then digitised and placed on a Photo CD. The intention is to create a panorama of the scene, however anyone who has tried this simply by butting the edges of photographs together will know the lack of success due to the lack of blending at the edges. To overcome this problem QTVR warps the images, mapping the overlap and stitching them together into one seamless panorama.

When a scene is opened within the QTVR player, this distortion is corrected through the unwarping of the part of the image that is within view. As you move around and explore the area, the QTVR software unwraps and displays your view of the panorama on the fly, resulting in a realistic visualisation of the node.

Like VRML, the viewing of QTVR is available through a plug-in for the Internet browser. The development of such scenes is however a more complex process requiring specialist software which at present runs only on the Apple Macintosh platform.

6. The Glasgow Directory

6.1 Introduction

With the introduction of VRML in November 1995, ABACUS was the first time able to incorporate 3D models of selected areas of Glasgow into their web pages.

As the VRML standards progressed (VRML2 followed by VRML '97), it became apparent that this language could offer far more than just the ability to view 'static' models, and extended research began into how the Glasgow Model could be adapted to suit these advantages.

http://cosmoplayer.com/products/player/
http://www.apple.com/
It achieves this by linking to a number of information sources, accessible through conventional Internet techniques such as lists, tables and search engines, as well as indirectly through the VRML itself. Unlike many Internet systems, there is no pre-set route to follow, or list of useful links. Information is accessed through intuitive exploration of the site, and therefore varies depending on both the user, and the chosen route. In this manner, the user becomes familiar with the virtual city, in much the same way as they would become familiar with the physical city. He or she may identify particular areas of interest, which can be revisited using the familiar routes, or accessed via browsing.

Current information sources include:

- Multimedia database of General Tourist Information
- Multimedia database of Glasgow Architecture
- Alphanumeric database of property addresses and street names.
- External Web-sites

A special feature allows architects and designers to download appropriate sections of the 3D model for use in proposed developments. Future additions to the system will permit design proposals to be integrated into the system allowing the audience to explore a number of possible urban design alternatives.

6.3 Recognition
Recognition and understanding of the virtual city is aided by the use of certain key ‘Lynchian Elements’. As already discussed, these help in the acquisition of spatial knowledge in both the real and virtual world.

- Extra detail is given to buildings in the model when they are perceived to be landmarks.
- The city streets and other routes can be easily identified by clicking on them.
- Each model segment is terminated at a distinct edge such as a river or a main street.
- Specified viewpoints (nodes) at junctions etc., help users understand their location in the virtual city.
- The subtle use of basic colours – blue for river, green for parks etc., help convey a better understanding of the urban fabric.

Recognition of individual buildings is achieved through the use of ‘layered’ data. Since the mode of the building itself may be nothing more than a basic block within the city context, the facade is expressed as a photograph displayed in another frame. This frame also displays some introductory text about the building, as well as linking to more detailed info such as QTVR interiors. In this way, the user can recognise the building by collating all the relevant information that is automatically displayed on screen as the building is accessed in the VRML model.

6.4 Uses
There are many potential applications for the Glasgow Directory, covering a range of interests and user requirements. Its flexible user interface means that the information gained from each session will be unique to each user. Here are some examples of system application:

6.4.1 Tourism:
A prospective visitor to the city of Glasgow can explore the virtual city before arrival in the physical city, resulting in a greater understanding of where to go and what to see. Browsing the city can influence choice of hotel, entertainment or shopping area, and transport networks may be
Although predominantly 2D based, these applications generally allow the user to plan a journey, giving both directions and information considered necessary to reach the chosen destination on time while allowing the user to search for hotels, petrol stations and restaurants etc.

As the use of web-based 3D technology has become more widespread, there has been a dramatic increase in the number of ‘cyber-cities’ appearing on the Internet. By adding the third dimension to existing applications, the user is able to navigate an environment in an easy, effective and intuitive manner, while accessing any amount of information relevant to their visit.

The poet Alfred Korzybski has already been enshrined in the prehistory of cyberspace for insisting on the divide between the representation of an experience and the experience itself. Virtual world builders far too often confuse the shell of a space with the experience of it, forgetting that the content is just as, if not more important than the container. The city is not purely a collection of static words and images, it is in fact completely the opposite. The city is bursting with life, dynamic, and full of character and special meaning. Traditional maps fail to convey this, due more to media constraints than creative desire.

Recent trends in computing hardware include the miniaturisation of everything. The processing power now available in the average PDA computer rivals that of a 1970’s company mainframe. While Moore’s Law holds true, it won’t be long before a fully featured handheld 3D UIS, capable of replacing the map, the guidebook and the reference manual, is affordable to every back pocket.

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Internet Resources
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Apple Software http://www.apple.com/
The Glasgow Directory http://iris.abacus.strath.ac.uk/glasgow
Abacus http://iris.abacus.strath.ac.uk/new/
The VRML site http://www.vrmlsite.com/