2D Interface to a 3D Environment A Proof-of-Concept: Coupling Two Software Applications for a Web-based Public Participation GIS

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Abstract

The inclusive Web-based Public Participation GIS (WPPGIS) domain has developed from the interactions of three principal domains: Public Participation (PP), Internet and GIS. Each two domains create distinct sub-domains: PPGIS, Web-based PP and Web-based GIS, each of which has been researched in its own right. A successful WPPGIS utilizes the dominant properties of the above sub-domains to create a viable system. The combination of the various characteristics, result in some inner tensions between the different components.

The high level of PP and GIS Technology are in some conflict. The high PP requires maximising the inclusiveness and empowerment of the public, which then requires simplifying the system to the lower common denominator. On the other hand, GIS Technology pushes forward, an area that is not a natural 'habitat' for the general public, thus creating a tension between the general public and the technology.

PP requires multiple communication and information channels. When addressing visualisation information, there are numerous challenges to display the information to the general public. The Internet media requires significant resources of Hardware, Software and “Humanware”. Although the physical resources are constantly becoming more available, the non-physical resource “Humanware” will always play an important role especially when interacting with 3D environments (which require additional skills). Thus, the need for a simple, light 2D interface to a 3D environment could assist in contributing and complimenting existing WPPGIS.

This project examined the development of a WPPGIS that links a 2D map to a 3D environment. The client interacts with a 2D map, selecting an origin point of view and a target point; thereafter, the system would generate a 3D rendered image that would subsequently be displayed back to the client. Unfortunately, the system was not completed in the given time. However, the principle features of the system are described and the various stages for future development are identified.

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Lastly I would like to thank Sigi my love for a magnificent year.

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4. MakeScene folder – the Window Application which generates the scene rendered images
5. changeScene folder – a solely assembly of MakeScene (a stripped version for the web application)
6. Data folder – Includes all data for the IMS and ArcScene. (including databases, Sxd file etc.)
7. Gallery folder – Image gallery from ArcScene and VTP, includes a short fly over film.

List of Abbreviations used in the text

ADO – ActiveX Data Object
AGILE - Association of Geographic Information Laboratories for Europe
ASP – Active Server Page
CASA – Centre for Advance Spatial Analysis
COM – Co`mponent Object Model
CORBA - Common Object Request Broker Architecture
CLR - Common Language Runtime
CSI – Client Server Interaction
DEM – Digital Elevation Model
DXF - drawing interchange file
EIA – Environmental Impact Assessment
ESRI – Environmental Systems Research Institute
GI – Geographical Information
GIS – Geographical Information System
GISCI – GIS Certification Institute
GML – Geographical Markup Language
HTML - Hypertext Markup Language
HTTP – Hyper Text Transfer Protocol
ICT – Information Communication Technology
IIS – Internet Information Service
IMS – Internet Map Server
INSPIRE - Infrastructure for Spatial Information in Europe
ISO – International Organisation for Standardisation
IT – Information Technology
NCGIA – National Centre for Geographic Information and Analysis
OGC – Open GIS Consortium
OO – Object Oriented
OS – Operating System
POV – Point of View
PP - Public Participation
PPGIS - Public Participation Geographical Information System
SP – Service Pack
SDK - Software Development Kit
SWOT – Strengths, Weakness, Opportunities, Threats.
UCL – University College London
UI – User Interface
URISA – Urban Regional Information Systems Association
VB – Visual Basic
VBA – Visual Basic, Applications Edition
VR – Virtual Reality
VS – Visual Studio
VTP – Virtual Terrain Project
W3C – World Wide Web Consortium
WGIS - Web-based Geographical Information System
WMS – Web Map Server
WPP - Web-based Public Participation
WPPGIS - Web-based Public Participation Geographical Information System
WWW - World Wide Web

1 Introduction

On entering the 21st century society has continued to adapt rapidly to the surrounding environment. The 2002 Johannesburg summit called for local action by civil society guided by a framework of sustainable development, combining Society, Economics and Environment into one arena. Technology plays a crucial role in this process although its interaction with the public is sometimes neglected.

This project is addresses the public interaction with the Internet and the Geographical Information System (GIS) as part of enhancing their involvement in decision making. Both of these technologies are continuously expanding and becoming a central part in daily life. A key element in this process is the manner by which people communicate with Information Systems. GIS technology has developed rapidly during the past few decades and the community has challenged its applicability to public debates.

Communicating the power of GIS to the public involves the competing requirements of simplification on the one hand (to facilitate maximum usage) and complication (to display its capabilities). The rapid expansion of the Internet has assisted in the former but the challenge of combating the complications still remains.

Snowden (2003) noted the need to ensure diverse access to Knowledge Management systems, as people utilise knowledge in various ways. Similarly, interaction with spatial elements requires various gateways to Geographical Information Systems, since the public perceive and comprehend spatial environments in different ways.

This paper will review the theoretical background and context for this project (section 2). Then section 3 introduces the project aims with relationship to a real-world scenario. The system architecture is dealt with in section 4 and the implementation follows in section 5. The discussion raises the key issues (section 6) and finally we conclude with a proposal for future developments7.

2 Background

In the 1970's Habermas introduced the term 'Public Sphere' as having a crucial role in the development of a democratic society (Calhoun, 1992). Habermas emphasised the influence of communication channels in this process. In a similar manner this dissertation involves three spheres that take part in public affairs: Public Participation (PP), Internet and GIS (Figure 2-1)[1]. Each sphere is complex and significant in its own right and has been researched and developed in many contexts. The interaction and relationship between each two overlapping spheres creates 3 sub-domains: Web-based PP (WPP), Web-based GIS (WGIS), and Public Participation GIS (PPGIS). Finally, an inclusive domain combining all three spheres has developed entitled Web-based Public Participation GIS (WPPGIS) and this is the core arena for this project (Figure 2-1). Although there is some natural connection between the spheres, this background sets to refine the various variables that interact between them. In sections 2.1 - 2.3 each sphere will be explored separately, thereafter section 2.4 – 2.6 will address the relationship between each two spheres. Section 2.7 will describe the tri-domain which basis the rationale for the development of this dissertation.

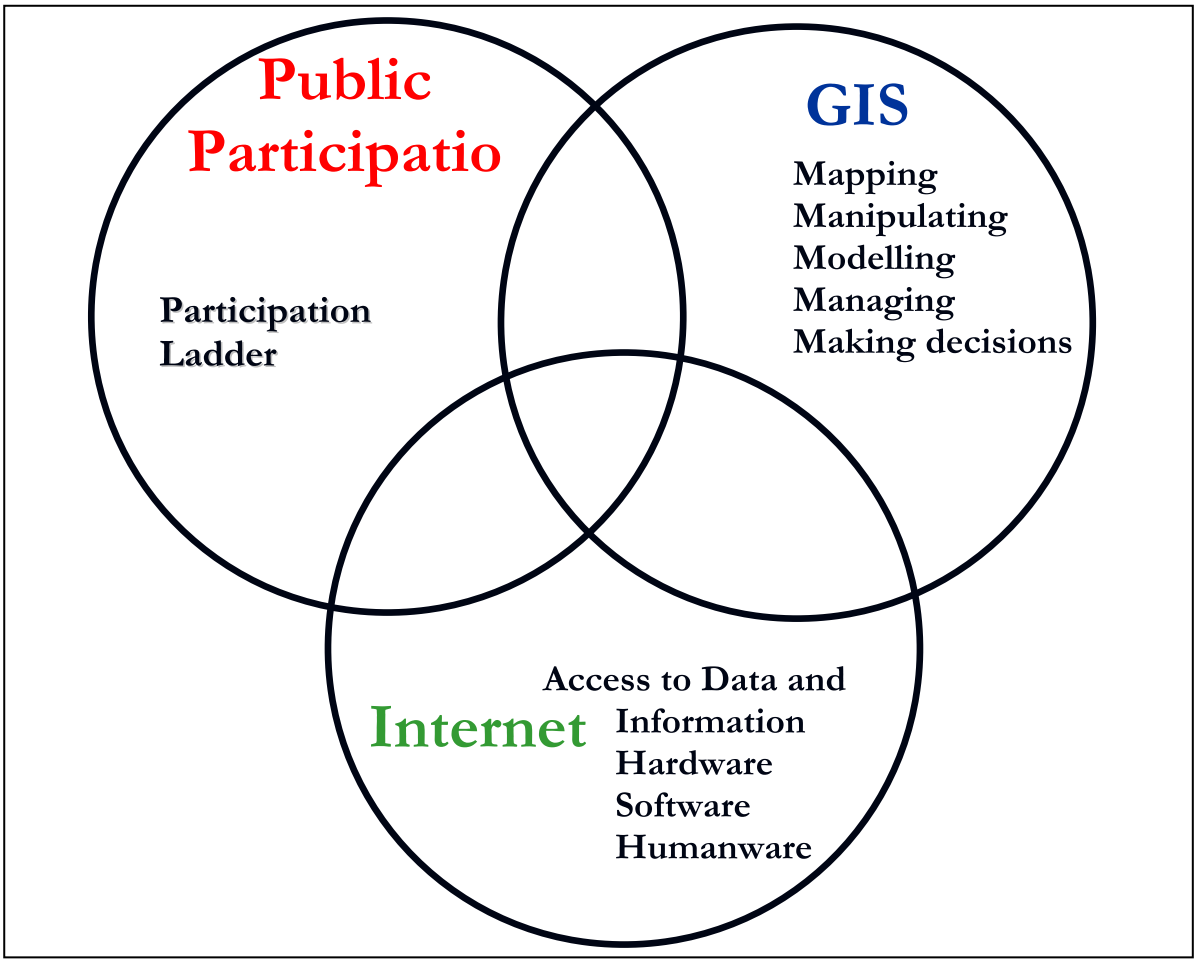

Figure 2-1 Three Spheres: Public Participation, Geographical Information System and Internet.

[1]Huang *et al.* (2001) illustrate the relationships between GIS, Virtual Reality and Internet in a similar manner.

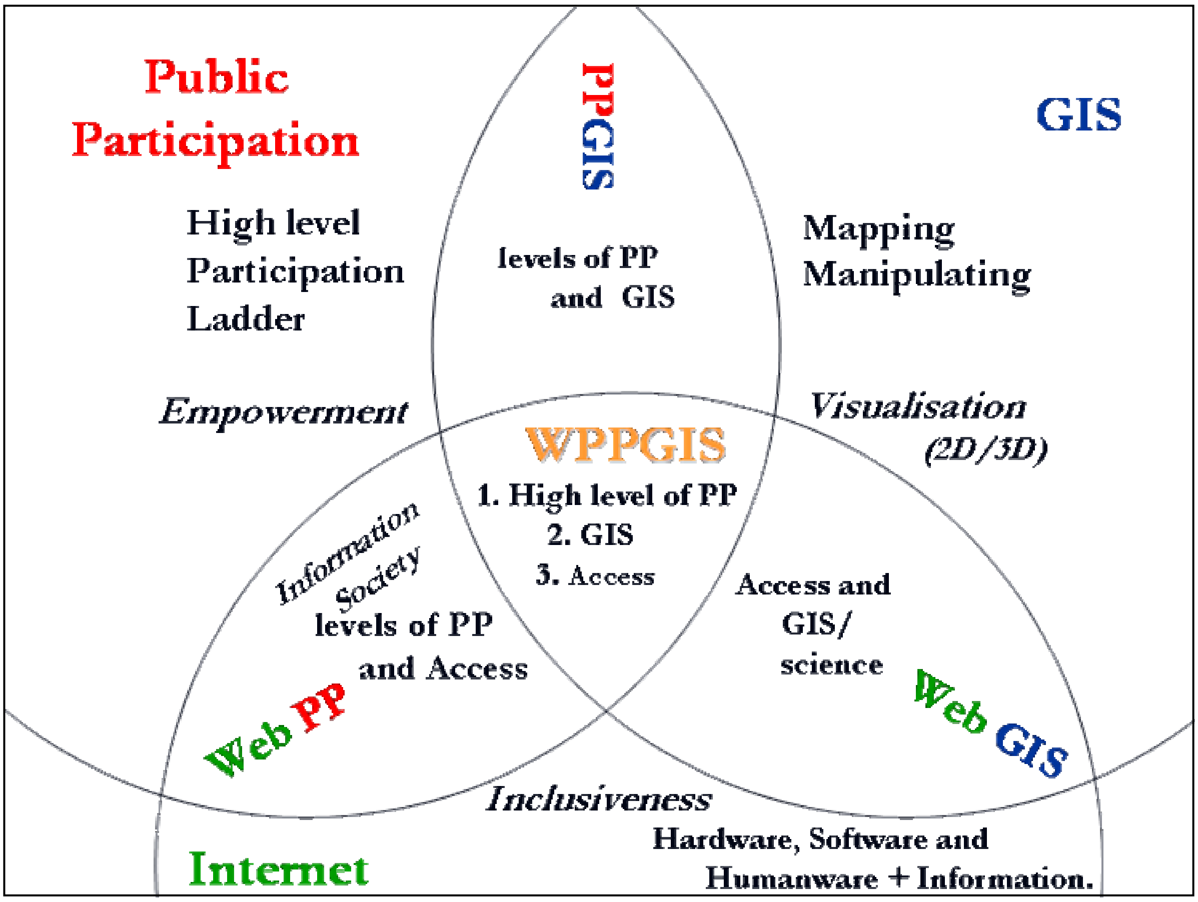

Figure 2-2 Creation of 3 sub-domains: Web-based Public Participation (WPP), Web-based Geographical Information System (WGIS) and Public Participation and GIS (PPGIS).

The synthesis of all three domains introduces the Web based Public Participation GIS (WPPGIS), see below.

2.1 Public Participation

Public Participation (PP) facilitates the involvement of citizens (in the broadest aspect) in social economic and political decision making. Not only does it encapsulate the traditional voting process but also permit a well-informed public to set, alter and criticise any public decision. Participatory approaches widen citizen activism and increase a pluralistic style in democratic processes (Krimerman 2001). PP is strongly linked to democracy, which is constantly developing and reforming itself.

In the past 3 decades the tension has increased between *representative democracy* and *participatory/collaboration democracy* (De Schutter 2002, Vigoda 2002, IAPP 2004). In a similar manner, since the 1960s PP has followed the transformation in democratic governing from “providing” solely services to “enabling” communities to initiate their own projects (Brooke 1989). Initially in a democratic society, basic participation was limited to public election. This presents the general public, on the one hand, with the possibility (and responsibility) to influence decision making, and on the other hand, allow for the authorities to renege from their responsibilities (Vigoda 2002). From the authoritative view PP is currently an essential dimension in the political arena, required for any sort of political activism. Additionally, there is an understanding that some information exists only in the public domain, i.e. tacit knowledge (even if not always articulated (Arnal & Burwood 2003)), and needs to be “mined” via PP to improve the outcome success of the decision making process.

There are many areas in which PP occurs, such as urban regeneration, rural development, transportation allocation, Environmental hazard distribution and Environmental Impact Assessments (EIA) (Craig *et al.* 2002). The demand for PP came from the planning discipline, where expansion of the participants from elite groups to a formal board base of constituents came about (Bruke 1979, p.88). Additionally, there is a strong environmental dimension to the development of participatory society which may even be the major driving force to both Public and Governmental bodies. This can be seen from the environmental oriented conferences in 1992 (Rio Earth Summit), 1993 (Maastricht Treaty in the EU), 1997 (Kyoto Protocol on Climate Change) and in 2002 (Johannesburg Summit on Sustainable Development). These promoted the notion of PP on a global scale, with strong support at the grass root levels. The Aarhus Convention (1998) has enforced freedom of access to environmental data and information, as well as the requirement from the United Nation Economic Commission for Europe is constantly pushing for accountability and transparency in environmental matters (Haklay 2003, United Nations Economic Commission for Europe 1998).

Three factors can be identified in PP:

1. Participants - Public and Stakeholders. The public characteristics, homogeneity and social awareness are all important elements. The public resources are normally scarce both physical and non-physical (e.g. financial and professional expertise) and considerable efforts need to be taken to ‘organise’ the entities in the public. A single accepted opinion is rarely achieved, and there are constant attempts to attract additional participants. In contrast to the amorphic public entity, other stakeholders (including the authorities) are normally well defined and well organised. Resources are more available and nearly all processes are in exclusive control by the authorities.
2. Communication and Interaction channels (quality, degree of influence and level of inclusiveness) – in order to facilitate any participation between the various

stakeholders there is a need to set down communication channels. Without these channels (both formal and informal) there is no possibility for PP. Information and Communication Technologies (ICT) have immeasurably increased the availability of information and the ability to communicate - thus facilitating PP.

3. Substance for the interaction - the cause for the interaction / conflict influence the participation level and the degree of commitment to the process (both quantity and quality). The scale of participants varies greatly, e.g. when the magnitude of influence increases the proportion of interested population is very small (percentage wise) although the actual numbers could still be very high (Carver, 2001) – the notion of NIMBY ("not in my back yard") is a major influence in the amount of participants.

These elements will now be addressed in the following paragraphs.

The term *Empowerment* describes the process of distribution of authority and power among the stakeholders, and this is crucial for PP. There are various levels of involvement in PP, these have been classified by Arnstein (1969) in his classic work *A ladder of citizen participation*, and have been adapted and explored in other fields (Carver 2003, Kingston 1998). The participation ladder can be schematically divided into non-participatory, semi-participatory and fully integrated participatory approaches: (Table 2-1).

Arnstein	Carver / Kingston (adapted from Weidemann and Femers (1993))
Degrees of Citizen Power (Partnership, Delegated power & Citizen control)	Public Participation in Final Decision
	Public Participation in Assessing risks and Recommending Solutions
Degrees of Tokenism (Informing, Consultation, Placation)	Public Participation in Defining Interests, Actors and Determining Agenda
	Restricted Participation
	Informing the Public
Non-participation (Manipulation & Therapy)	Public Right to Know

Table 2-1. Participation Ladder. The original classification by Arnstein (1969) and the development in the 1990s.

The borders between the various levels (both vertically and horizontally between the different classifications) are vague, and can alter in various stages of the course of action. This paper does not have the scope to review in depth these categories, but just to emphasise that the various levels of PP are based on communication of information.

Challenges

When encountering PP there is a constant challenge in upgrading PP and maximising the inclusion in the decision making process. In order to facilitate such a process many obstacles need to be removed (from all the above factors), such as the channels of communication and information and the tools that are displayed for the public use. This project elaborates on an intensified method for PP, which incorporates usage of the Internet and Geographical Information Systems (GIS).
The research assumes that PP requires multiple communication and information channels, which maximises PP.

2.2 Internet

The concept of a cyber network has developed since the 1960's with the significant emergence of the World Wide Web (WWW) from the 1990's. During this time there has been significant progress of the technology both in the computer hardware and software, and in the development of new communication channels (e.g. increase of broad band). The infrastructure required for this technology, both public and private, is becoming increasingly cheaper, abundant and reliable, thus facilitating the development of complementary services.
While Internet incorporates numerous elements, there are two important factors that are significant in this project context: Accessibility and communication channels. Both play a role in immediacy to information and data.

Access

The use of Internet to disseminate data and information is a double-edged sword. On the one hand the simple step of publishing information on the Internet allows for millions of people to view and access the relevant information. One the other hand, if used alone, electronic media can possibly exclude a significant portion of the public[2]. Furthermore, retrieving the desired information can be problematic, and there is always a challenge not to drown in the sea of Web pages.

Communication channels

As the normalisation of access to the Internet increases, it is possible to establish and formalise communication channels between various stakeholders, including the general public. These

[2] For world Internet access see International Telecommunication Union (2004).

channels could be a one-direction form (e.g. publishing information on a Web site), bi-direction communication on a one to one basis (e.g. emails), and the establishment of a virtual meeting (e.g. chat rooms and discussion boards). No matter what channel is used the Internet has significantly transformed societies' communication channels from hardcopy letters to the various electronic forms.

2.3 Geographical Information System

It is held that the first Geographical Information System (GIS) was a Canadian GIS in 1967 which was the pioneer in this field (Longley *et al.* 2001). The increased usage of GIS in many disciplines and industries, including urban development (Laituri 2002), has intensified in the last decades (Association for Geographic Information 2004, Dangermond 2002). The availability of technology, software (and complementary hardware), digital datasets and professional personnel has enabled the expansion of GIS at all levels and in many communities.
GIS can be described to encapsulate the following 5Ms:

1. Mapping
2. Manipulating,
3. Modelling,
4. Managing, and
5. Making Decisions

1. Mapping is the core outcome of GIS and comes under the discipline of cartography. The various possibilities, types and capabilities, including 2D and 3D visualisation, give the fundamental *power* to GIS (including 3D models e.g. Coleby *et al.* 2004, Buckley *et al.* 2000).
2. Manipulating and analysing the data is another key functionality in GIS, and increasingly additional capabilities (such as spatial statistics) are encapsulated into mainstream GIS software (Goodchild 2003).
   Modelling functionality is common in environmental scenarios and there are constant developments in this area. Specifically it is worth mentioning the development of fully integrated systems (rather than coupled) such as in environmental management (Fedra 1993), which set the basis for this project.
3. Managing resources (especially environmental) has become typical of IT systems and the maturity of GIS has increasingly found a prominent role in these systems. In

addition, the increased availability of spatial data[3] enhances the potential use of spatial systems.

4. Finally, there is the usage of GIS in delivering a set of solutions that could be directly utilised by the decision makers (Densham 1991).

The various usages of GIS in Virtual Reality (VR) environments and 3D visualisation have many commercial applications and have been reviewed by (Haklay 2002b). Full 3D representation is only required in urban environment and landscapes abundant with overhanging cliffs, otherwise the 3D GIS visualisation is more precisely considered to be composed of 2.5D datasets[4] (p.71 Longley *et al.* 2001). VR emphasises on the interface and interaction with the data, accompanied by the ability to simulate the real world (rather than just imitate it, as seen in computer games) (Haklay 1999). In the context of this paper, VR can assist in displaying information to the general public, especially in relation to landscape and urban regeneration projects (Fisher & Unwin 2002), although there are still some practical shortcomings hindering vast implementations (Davis 2003). Nevertheless, the developments of Cyber cities (so far mainly in gamming and research functionalities) have demonstrated the possibilities of these systems, especially in urban environments (Doyle *et al.* 1998). Issues such as 3D topology and 3D databases have intrigued researchers for the last decade and there is still considerable amount of work to be developed in this field (Batty & Longley 2003, Stoter & Zlatanova 2003).

The development of GIS into an accessible “out of the box” software has led to an interesting discussion regarding the expertise required for using such systems. Lack of theoretical and scientific knowledge concerning GI systems allow for sub-optimal analysis and to the emergence of critics concerning the usage of GI systems (Monmonier 1996, Openshaw 1996, Wright *et al.* 1997). This is especially true when introducing GIS into the public domain (section 2.6)

[3] 1 Terra byte each day, Goodchild (2003)
[4] This project will use the inclusive term of 3D.

2.4 Web-based Public Participation

The Combination of Public Participation and Internet produced a dynamic new domain Web-based Public Participation (WPP) which combines the energy within PP and the Internet communication boom (Research Center on Information Technologies and Participatory Democracy 2004). There have been various terminologies for this domain such as: Online democracy/ E-government/ Cyber Democracy and *Information Society*. The expression of this notion can be seen across the globe with emphasis in the developed countries (e.g. EC Action Plan entitled 'Europe's Way to the Information Society' (Commission of the European Communities 1994). Craglia & Masser (2003) review the development towards Information Society in the EC with relation to GI.

A major contribution of the Internet to PP is the various communication channels which facilitate communication both vertically (number of participants) and horizontally (the communication capabilities). The Internet and electronic medium have produced many opportunities for this interaction - from quick, easy and low-cost dissemination of information, to the ability to receive multiple feedbacks from the general public (Conroy & Gordon 2004). Viewing these interactions in the dimensions of Time and Space displays the various levels of possible interactions (Table 2-2) (Dix *et al.* 1998)

		Place	
		Same Place (Local Contact)	**Different Place (Remote Communication)**
Time	**Same Time (Synchronous)**	Face to Face Interaction, Public Meeting	Telephone, Tele-Video-Conference, Groupware
	Different Time (Asynchronous)	Post-It Note, Sequential and Accumulative Tasks	e-mail, News, Fax, Web-based Distribution.

Table 2-2 Cyber-communication matrix Time / Space (after Dix *et al.* 1998)

Dix (1995) earlier describes a more complex concurrent vs. synchronised communication situations, which could possibly apply to the virtual society entities while attending virtual public meetings (or video public conferences).

Similar to Arnstein's (1969) Participatory ladder Smyth suggests an e-Participation ladder (Table 2-3 cited in Carver 2001).

Increasing participation	Online Decision Support Systems	Two - Way	Level of Communication
	Online Opinion Surveys		
	Online Discussion		
	Communication Barrier	One- Way	
	Online Service Delivery		

Table 2-3. Cyber Participatory Ladder, after Smyth (cited in Carver 2001).

Adapting Arnstein's Participatory ladder to the information society reality, including the various levels of PP could be classified by the level of communication.

Building upon the participation ladder, the lower levels demonstrate the informative process in PP where the information is passed to the stakeholders – however, this is a one-way communication channel. In the higher levels of PP the communication is bi-directional facilitating more active participation (this process is restricted to the electronic medium). As part of participatory approach, additional usage of the electronic medium introduced the usage of public opinion Web-based surveys (Carver 2003, Haklay 2002a).

Kingston (1998) among others conclude that the Internet is a successful platform to disseminate information and as such is most appropriate for PP. The common obstacles in PP, such as process restriction to time and place, domination of individual, social classes (i.e. gender, shyness) can be diffused through WPP (Leitner *et al.* 2002, Kingston *et al.* 2000). These include (Carver 2001):

1. No restriction to geographical location (especially now with the wireless Internet connection)
2. No restriction to time constrains (Only restricted to the access to the Internet)
3. Reduce social constrains – the virtual façade 'frees' some emotional and non-physical constrains permitting participants to express their feelings and thoughts without personally exposing themselves.

The ability to select information from a gamut of sources in addition to personalising the query, introduces another important advantage to WPP.

2.4.1 Challenges

The attractiveness of new technology and specifically the Internet has caused some dazzle (or 'technological enthusiasm') which may have hindered the core aim of PP. Once using the Internet as The communication channels, as much as there might be an increase in PP, there may be decrease in the **inclusiveness** of the general (non computer-literate) public. The inclusiveness challenge includes physical and non-physical elements. The relationship and correlation between Internet Access and Social inequality has been greatly discussed under the new phrase "Digital Divide" which gives expression to the intuitive thought that the lower socio-economic classes have less access to Internet (Kozma *et al.* 2004). This includes public that does not have physical access to the Internet (hardware, software and communication-ware), or that does not have the required "Humanware" (i.e. non-physical resource as education and computer literacy) (Carver 2001). "Humanware" includes the skill to use the displayed technology and the ability to comprehend the information in terms of language and cognitive skills.

Although Internet seems to break down the spatial barriers, there are many advocates arguing that physical access to Internet does not translate to equal access (Niles and Hanson 2003) and that Tobler's First Law of Geography[5] may still exists in the cyber world.

In any case, it should be noted that the Internet is not going to eliminate the 'face to face' interaction and cannot substitute the personal contact that is required for all social, economical and political activities (Niles & Hanson 2003). Furthermore, the skill to harvest information from the Internet sphere is a major constrain, which is socially/ culturally, confined.

It may be concluded, so far, that communication channels in the physical and in cyber world play a significant role in the accessibility of any information system.

2.5 Web-based GIS

The merge of GIS and Internet has occurred naturally, with the dissemination and expansion of both spheres. The popularity of the Internet since the mid 1990's stimulated the integration of Geoinformatics into the cyber world (Xue *et al.* 2002). Web-based GIS (WGIS) allows for the access of a powerful tool in a timeless and space-less environment[6]. WGIS can be seen as an inbound and outbound procedure. The former allows integration of remote data into local GIS processing, while the later uses the WWW to distribute data, information and capabilities to remote users. In the past decade this activity has greatly expanded, facilitated by the Open GIS Consortium (OGC), which coordinate between the various bodies and promotes the *interoperability* in the GI industry (Open GIS Consortium 2004).

[5]"everything is related to everything else, but near things are more related than distant things" (Tobler 1970)
[6] dependent only on Internet access.

The potential benefits for WGIS are enormous, including published static and dynamic maps, access to datasets (spatial and non spatial) and the dissemination of spatial analysis. In the early stages of these systems, WGIS was mainly used for displaying simple map functionalities and to disseminate spatial data thorough WWW Clearinghouses (Crompvoets & Bregt 2001), which have been strengthened by initiatives such as the National Spatial Data Infrastructure in the US and the e-Europe initiatives (Cragila and Masser 2001).

The proliferation of the Internet network capabilities and the limited ability to use the data, shifted the emphasis to the coupling of GIS with Web servers, thus allowing for increase GIS functionality via the WWW (Coleman 1999, Peng & Tsou 2003). This includes introducing to remote users the possibility to generate personal queries, analyse ‘what if’ scenarios and other Web-visualisation techniques (Doyle *et al.* 1998); however, most Internet GIS packages are limited to 2D static maps (Huang 2003).

Usage of WGIS provides additional advantage from the *data* point of view system management. Managing one centric system (and not multiple desktop systems) is a significant advantage. This can be increasingly seen to the expansion of development in the ‘thin’ client systems (Smith 2004b).

Various system architectures have been developed, which distribute the three main functionalities in WGIS between the client and the server: Rendering (Presentation), Processing (Logic) and Data, (Peng & Tsou 2003). These systems can be divided into Two-Tier, Three-Tier or *n*-Tire architecture configurations (Huang *et al.* 2001, Huang & Lin 2002, Peng & Tsou 2003). Section 4 describes the architecture design relevant for this project.

2.5.1 Challenges

Similar to other Web systems, there is a constant demand for a reliable, efficient and fast system, in order to allow for full incorporation into the IT systems. The ability to translate, both data and information, from remote sources into comprehensible working ‘material’ is a major concern, especially with the vast amount of geographical data that is collected and available online (Goodchild 2003). Licensing the datasets for Internet usage is also problematic (Hudson-Smith & Evans 2003), especially with multiple data sources. Goodchild *et al.* (1997) describes three levels for interoperability in GIS: *Technical*; *Semantic*; and *Institutional* level which is the most challenging due to the cultural factor. The interoperability can apply both to inbound and outbound interaction and are intensified when taking into account the Internet environment. Some critiques would argue that the dissonance between the speed of the Internet and a personal computer dismiss many development initiatives (Manifold 2004a)[7]. Wright *et al.* (2003) critics WGIS for shortcomings as: problems with management of non-spatial data, Data validity and accessibility, Data Time series, 3D Visualisation, and coupling computational models within WGIS. Hence, the OGC has taken a prominent role in researching these interoperability challenges that are accompanied by lively debates[8].

2.6 Public Participation GIS

The term Public Participation GIS (PPGIS) was introduced from the planning profession (similar to PP) in the mid 1990s and has developed under the auspices of the research on "GIS and society" (Obermeyer 1999). GIS has expanded from the informative and disseminative information system to a more "Community – Integrated GIS" (Harris & Weiner 1998). The many variants to PPGIS illustrate the richness and vibrant of this subject as CiGIS: Community-integrated GIS, P-GIS: Participatory GIS MIGIS: Mobile, Interactive GIS, P-Mapping, P3DM: Participatory 3Dimension Modelling, which all bring together GIS into Society.

Carver (2003) describes the development of PPGIS as the outcome of the debate between the "techno-positivist GIS-ers on the one hand and GIS-hating social theorists on the other" [9] (p.65). The terminated Varenius Project and specifically initiative I-19 (NCGIA 1998) amongst others have strongly promoted the research and developments in this area. A recent book by Craig *et al.* (2002) brings together the key researchers and displays a wide variety of applications and illustrates the key issues in this domain. Nowadays, Urban Regional Information Systems Association (URISA) and Association of Geographic Information Laboratories for Europe (AGILE) appear to be the platform for the development of initiatives in this field (Carver 2003), and have been encompassed by a yearly conference on PPGIS (URISA 2004).

[7] Even so, Manifold has fallen under the pressure and recently announced (25 Aug. 2004) the implementation of a WMS in SP1 for Manifold 6.0

[8] for an example see one of many lively debates generated by the Geographical Markup Language (GML) initiative (e.g. Manifold-L user mail list, http://lists.directionsmag.com/discussion/read.php?f=29&i=36911&t=36911, [Accessed 22nd July 2004]).

[9] This is somewhat reminiscent of the Snow - Leavis controversy in the 1960s between knowledge of the Sciences and the Arts (Kimball 1994).

The interaction between GIS and the Public comes about in a dual way. On the one hand customising *public goods* (i.e. space and land) with GIS requires (at some stage) the affirmation by the public, and on the other the advanced professional tools with possible straightforward visualisations attract the public. Furthermore, the introduction of GIS into PP can be attributed to various notions such as:

1. Natural technology dissemination; and
2. Social responsibility.

1. The manner in which technology disseminates into society is complex and is due to many factors, occurring at all levels and in various channels (conscious and sub-conscious). This paper does not have the scope to discuss this issue in depth: the question whether humans controls technology or vice versa is one with which the GIS community, together with the entire scientific community is struggling to answer (Haklay 2004 Pers. Comm., Sui & Goodchild 2003). In the case of GIS the process is on going and could be related to the debate concerning recognising GIS as a separate profession and discipline (GISCI 2004). The involvement of PP in the spatial domain instigated a demand for spatial tools. This was supported by the key role of Indigenous Spatial Knowledge and Indigenous Technical Knowledge in the participatory process (McCall 2003).

2. GIS has integral links with equality and equity, but may easily go astray (Harris *et al.* 1995, McHaffie 1995, Talen 2001). Social responsibility and equity is always a burning topic, which was eagerly introduced into GIS by Pickles in his edited book ‘Ground Truth’. The GI technology is challenged by several co writers to transform itself from an elitist technology and enhancing power tool to a shared public technology (Pickles 1995). The Participation GIS has encouraged community involvement, leading to a Bottom-up approach, in which the GIS systems are adapted to the wider public (Abbot *et al.* 1998). This is nearly universally accepted as providing an overall positive and healthy impact on society. However, due to the powerful tool and as part PP, the political context plays a crucial role in any PPGIS (Ghose & Elwood 2003), which is not only confined to developing countries (Roche 2003), or in other words “GIS, [...] is only as good as the local politics” (p.4) Abbot *et al.* (1998).

GIS can facilitate PP at the various stages of the participatory discourse. Laituri (2003) examines four components for assessing PPGIS: Context, Connectivity, Capabilities and Content. Laurini (2001) divides PPGIS functional capabilities into 2 levels: Exploration/ communication support and enhanced analysis/deliberation support. In each stage the usage of GIS differs in the functionality of the GI tools and encompasses different interaction with the user.

One of the major impacts of GIS is in its ability to translate complex plans and spatial data into understandable layman information. Presenting GIS in a simplified and supervised manner reduces the complexity of the system and with some guidance facilitates the usage to the general public (Carver *et al.* 2001). This also allows for decision makers and politicians, in addition to the general public, to acquire comprehensive understanding of their project, leading to an efficient decision process. Commercial desktop GIS might well be too complex and elaborate to be used by the general public, thus customisation and tailoring GIS to the usage by the wide public would be of sure benefit (Peng 2001).

GIS has been introduced to the public in various ways (Leitner *et al.* 2002), these can be divided into two forms: physical access to the technology and electronic/ cyber access to the technology. The former ability has been demonstrated in various projects in rural communities such as in Spatial Decision Support Systems for Groups (Jankowski & Stasik 1997b) or in Mobile Interactive Geographical Information System (McKinnon & McConchie 1999), where GIS was used in a Participatory Rural Appraisal. The latter cyber form will be discussed in section 2.7.

The expansion usage of GIS in EIA (Rodriguez-Bachiller & Glasson, 2004), and the requirement to involve public hearings in EIA introduces GIS as a common platform for this communication. In such situations, a successful PPGIS must incorporate trust and credibility between the stakeholders, and a mutual accountability of the data and the analysis must exist (Kingston *et al.* 2000). Additionally, it should be associated with the legitimacy of the planning process and of local government (Harrison & Haklay 2002). And as such, the system must maximise the transparency, be accountable, simple and respectable to all stakeholders (McCall 2003).

Much of research has been devoted to understand the most effective visualisation communication to the general public (Krygier 1998). 2D maps have been commonly used for centuries, however 2D maps have limited capabilities to display spatial information. 3D visualisation, on the other hand, could convey a great deal of information to the observer in an easy and exciting manner. The possibility to display 3D models to the public adds value to the Participation Process (Coleby *et al.* 2004, Gudes *et al.* 2004). This possibility is increasingly becoming viable due to the development in technology and the availability of computers and professional resources. Simple terrain 3D environments are available in most GIS software, but differ with the various capabilities (Appleton *et al.* 2002). However, the financial resources for 3D modelling can be considerable, thus becoming non-applicable for PPGIS projects. Commonly, specialised software is coupled to traditional GIS packages to increase the performance and easiness of generating 3D models.

2.6.1 Challenges

Introducing GIS tools to the participatory arena may complicate and limit the PP process in several ways (Casey & Pederson 1998), this is influenced by:

1. characteristics of the Public;
2. complexity of GIS; and
3. the physical resources required for GIS.

1. When addressing the public in a participatory process, there is a need to identify the characteristics of the community in order to address problems and to decide on the scope of the participation. Erik de Man (2001), among others, concludes that access to GIS doesn't automatically enhance PP. GIS could be necessary and enabling for PP but there is a critical need to address the social and cultural context in which this process occurs (Carver 2001). One must remember that the essence of the participation is to allow for the community to be part of the planned transformation, or as Pain and Francis wrote (2003):

   > "Participatory approaches did not originate as a methodology for research, but as a process by which communities can work towards change." (p. 46)

2. GIS, as a powerful tool can be operated in the expert/ professional domain, away from the general public (Carver 2003). In an intensified manner, when compared with WPP, the issue of participant inclusiveness arises. 'Digital divide' strongly exists in GIS and considerable efforts needs to be made in order to facilitate such technology. More over, Laituri (2002) highlights three problematic issues that result from the interaction of GIS and marginalized members in a group: 1. Limitations inherent in technology 2. Different capabilities of the participants 3. Homogenisation of the knowledge structure (by the standardisation of the system and facilitator). Introducing GIS into PP is not automatic, "but with the appropriate approach – culturally as well as technically" (p. 566, McCall 2003) is viable. An obvious solution for these tensions is to promote education and training sessions to PPGIS users (Merrick 2003).
3. GIS tends to be expensive (especially the datasets) and professional costly, thus bringing to a Top-Down environment (Abbot *et. al.* 1998) and to inadequate use of the system by various groups (Sieber 2002).

2.7 Web-based Public Participation GIS (WPPGIS)

The development of Web-based Public Participation GIS (WPPGIS) has been prophesied by many and began to be implemented from the mid 1990's (Chang 1997, Kingston 1998, Abbot *et al.* 1998).

This domain has naturally derived from the combination of the 3 sub domains: PPGIS, WPP and WGIS. Sajakoski (1998) gives a good review of WPPGIS and concludes that future technological development will enhance the feasibility for WPPGIS. Carver (2003) has written a thorough review about WPPGIS (including a SWOT[10] analysis) and states that although there is increasingly usage of Web map services "there are still comparatively few instances of real-life usage […] within public participation" (p.65).

A successful WPPGIS utilises the dominant properties of the above three sub-domains (
Figure 2-2). From the **WPP** that is characterised by Low-Medium level of PP and high access to information the WPPGIS will demonstrate the high level of access, which contributes to the *empowerment* and *inclusiveness* of the systems. Furthermore, this allows for equal footing between the stakeholders in relation to data and information. **PPGIS** is characterised by high levels of PP and usage of strong technology of which a WPPGIS will take advantage of the high level of PP. Finally the **WGIS** is dominated by high access and Technology of which the WPPGIS will demonstrate the usage of Technology.

The combination of the various characteristics causes some tensions between the components of the domain (see
Figure 2-2). The **high level of PP** and GIS **Technology** are in somewhat of a conflict. The high level of PP strives for maximum inclusiveness and empowerment of the public, which then requires clear and simple methods of interaction. On the other hand, GIS technology pushes forward to the forefront, an area that is not a natural 'habitat' for the general public, thus creating a conflict. A possible resolution for the clash is by displaying various gateways to the WPPGIS, in such manner that the system can facilitate different users' preferences[11].

Peng (2001) lists the following 4 functions as System Requirements for a WPP Systems (while Carver *et al.* (2001) provide similar requirements however they include the crucial social and political elements). These are Exploration, Evaluation, Scenario building, and Forum (meetings).

- Exploring the spatial data by various means reduces ambiguity and if distributed equally allows for a common ground between the various stakeholders.
- Evaluating the various alternatives in the process allows the public to display their judgment. The various means of the evaluation depends greatly on the GIS tools available.

[10] Strength, Weakness, Opportunities, Threats.
[11] Internet Access mitigates the entire degree of PP, but it does not cause direct internal conflict between the properties.

- Scenario building permits the public not only to evaluate alternatives but also to generate them. However, generating alternatives is a complex process which may be unrealistic for the general public in addition to the natural limitation to these modelling systems.
- A virtual meeting, Forum, allows the public to share and express their thoughts on the project. This virtual communities should display spatial and non-spatial information and be ‘public centred’ (Harris & Weiner 1998).

Peng (2001) also lists 8 generic technical function requirements for WPPGIS:
1. Internet Web-based client server architecture, based on natural interoperable platform
2. Distributed database management system support.
3. Map-based coupled with Hypertext Markup Language (HTML)-based graphic user interface (allowing for direct spatial interaction).
4. Analysis functionality for ‘what-if’ modelling
5. Multiple communication channels between the public and the stakeholders.
6. Online selecting preferences (voting online)
7. Scalable system allowing for expansion of data and capabilities.
8. Compatible to standards (such as ISO, OGC and W3C)

This project emphasises the 5^{th} point, not only multi communication channels are needed, but multi interfaces are required to maximise public interaction with spatial information.
This dissertation will follow these lines to generate a prototype tool to allow the visualisation of 3D environments from 2D perspective. There have been preliminary attempts introducing 3D into WPPGIS such as Virtual Geographical Environment (Li & Lin 2002, Smith *et al.* 2002), but with limited success. Thus, the proposed tool can be incorporated into a WPPGIS as one of the gateways to access the data and information.

2.7.1 Challenges

Carver (2001) states that the following 3 reasons which hinder WPPGIS:
Political difficulties, lack of resources (physical and non-physical), and readiness of the public.
Alternatively (Carver *et al.* 2001) identify IT training, accessibility to the Internet and copyright issues as the main hurdles for a successful interaction between the Public and the WGIS.
Peng (2001) gives a schematic review of the various levels of WPPGIS. He describes a Taxonomy based on 2 dimensions: Level of participation and Degree of functionality and interface. The levels depend on the degree of sophistication and interactivity, and as such there should be emphasis not only on the system sophistication but also on the user interface sophistication. He concludes (among

others) that while WPPGIS is suppose to enhance PP, issues as accessibility and inclusiveness, user friendly systems (and tools) and accountability are all more than non-technical issues that must be addressed for a successful WPPGIS. Additionally, new technology is not always compatible with existing systems; thus even if the information is available on the Internet it may not be accessible to the general public. Many systems require additional Plug-Ins (e.g. Java applets or 3rd party Plug-Ins (Omer 2003, Waters 2002)) which may not be compatible to the individual system or which requires a ‘stronger’ computer to run the application. A Web-Server based system can bypass this obstacle (see WPP for other Web strengths).

2.7.2 Multiple Gateways to WPPGIS

With the growth and dissemination of the Internet many PPGIS have some elements of WWW interaction. This is due to the suitability and easiness of the Internet for the usage of PPGIS additional to the desire of the researchers to use bleeding-end technology. A study in the UK (Castle 2004) concluded that there is a strong adoption of GIS technology through the WWW, even among disabled population (physically challenged). However the value of “93% of all participants were confident of operating the GI System” (p. 105, ibid) seems very high value in this context (especially without knowing the total number of participants).

A key concept to the rational of this research is the understanding that optimal usage of any multi-accessible system requires multiple different gateways for various users (such as in urban planning (Manoharan *et al.* 2002). Since WPPGIS is a multi-faceted issue, a multi-gate to such system would be most appropriate to address this aspect. This concept has already been up-taken in different areas such as Knowledge Management Systems (Snowden 2003) and in software applications (e.g. Evrsoft (2004) incorporates 3 interfaces to an HTML editor: beginner, intermediate and professional).

In 2001 a special workshop was held in Italy on ‘Access to Geographic Information and Participatory Approaches in Using Geographic Information’. The meeting report concluded that there are three main research areas suggested (Craglia & Onsrud 2003):

1. The contribution of GIS to the context of the participatory systems and the possibility to personalise these systems for public uses;
2. Understanding “how different communities represent their spatial stories” and problems, and how such representations (including 3D visualisation) contribute to PP; and
3. Study the public learning environments with Geographical Information & Technology.

Providing an accessible interface to 3D environments fits into the two latter conclusions, and is part of the frequent conclusion by many researchers that “efforts should be made to make the systems user-friendly and easy to understand” (p. 903, Peng 2001). The need to tailor participatory systems to a particular use and to a particular audience, including user interfaces (Gudes et al. 2004), is increasingly suggested in the literature. These include both technical elements and especially social/cultural elements (Carver et al. 2001).

3 Project Aims

3.1 Proof of Concept

This research addresses the potential of Web-based Public Participation Geographical Information Systems in conveying 3D visualised environments. The umbrella research topic tackles the following questions: to what extent does technology facilitate PP? Or specifically can a 2D interface to a 3D environment enhance PP via Internet media? This project investigates the development and implementation of such a system.

PP requires multiple communication and information channels, especially when communicating spatial information. This is intensified when considering Internet media, which requires significant resources of hardware, software and "Humanware". The two former resources are financially constrained which although becoming constantly cheaper, still restrict many users, especially in the developing countries. The latter one refers to the human interaction with 3D environment, which require learned skills to manipulate such objects in addition to certain level of technological competency. Thus a simple 2D interface to a 3D environment could contribute to PP and complement existing WPPGIS, while facilitating interactive exploration of a modelled 3D environment. The concept of a dynamic link between two views (i.e. 2D and 3D) has been implemented in many GIS/Visualisation software applications. This has even been introduced into the WWW environment (e.g. Idealista 2004 and Societe Numerisation de Ville 2004 combine a 2D map with pretaken photographs), but only with limited user flexibility regarding both navigation and visualisation. This project tries to deliver a 'low-tech - hi-tech' solution (for maximising accessibility) using simple functionalities in a complex environment. Hence, the project attempts to demonstrate the concept of a PPGIS which allows the user to interact with a 3D environment through a 2D interface in the Internet medium.

From a technical aspect, the research will explore the Web interactiveness with a GIS, specifically, coupling two systems: one serving 2D maps over the WWW and the other rendering 3D images. This element of the project can be perceived as driven from the current notion in the IT domain for *Component based* applications design by deploying various toolkits and components for customising systems development (an example of such a tool kits are Balovnev *et al.* 2004 and OpenGL 2004). Hence this project attempts to implement a system for coupling an Internet Map Server (IMS) with visualisation software.

It should be emphasised that this research does not question the capability of the Internet to enhance PP, but rather introduces an alternative gateway to compliment existing WPPGIS (based on the certitude of ‘one solution does NOT fit all’).

3.2 Scenario

The following scenario was introduced to illustrate the usage of the proposed system, which is based on a common urban planning procedure. The background scenario sets the context of this project in an urban sprawl project development that incorporates PP into the planning process. Such project is currently under discussion in the western hills of Jerusalem, Israel, where a proposed plan is introduced to develop satellite neighbourhoods on open green spaces and forests (Sustainable Jerusalem 2004) (Appendix 9.3). The urban participatory planning process utilizes the conventional communication channels and the Internet, to display the proposed plans and to receive the public feedback. Assuming that a significant portion of the public is able to interact with a basic Web browser, the client (any member of the public) may want to obtain information about the proposed 3D model. The scenario incorporates a gross detailed landscape environment of the Jerusalem hills, to the degree of building blocks (but without any additional details). This scenario is reasonable both in relation to the potential public campaigns and from the requirement to generate a 3D virtual environment in a limited time frame and available data (Krygier 2002).

3.3 System Requirement

The basic system requirements are not complex and consist of a *client*, who sets the view settings, and of a *server*, which generates the image from the existing 3D model environment (based on the client’s personalised parameters and displays it back to the client. A simple and clear User Interface (UI) is required, to facilitate the public in generating a Point of View (POV). Two POV are required: for the origin viewpoint and for the target point that is being viewed. The following components are the principle components in the prototype UI.

1. A 2D base map that will provide a platform for the POV setting.
2. An information panel displaying customisation information of the POV.
3. An image panel displaying the rendered image.

After testing 3 leading GIS software visualisation, Appleton *et al.* (2002) conclude that there is not one best GIS software for visualisation, especially when considering the WWW and financial constrains. When taking into account the possible scenario that might involve an application of this sort for a NGO (engaged in a participatory process), limited financial resources can be assumed.

Hence, the research originally attempted to experiment with low cost GIS and freeware as the software. This supposition went through some modifications during the development of the research.

3.4 Scope

The nature of the dissertation allows for the development of a *proof of concept* and the framework for a prototype system and by no means is able to develop a fully functional system. The aims are to show the possibilities and to map the way for future developments while describing the experience of a geomatic professional developing such a system. In the context of PPGIS, Laituri (2003) examines 4 components for assessing such systems: Context, Connectivity, Capabilities and Content, this project aims to enhance and develop the two middle components.

The project did not follow a typical Functional Requirement Study that could be seen suitable for such project (Ferguson 1990), but took into account some *a priori* requirements as software availability and system development environment, which resulted in a similar process.

4 System Design

4.1 System Architecture

Any Web application incorporates a particular relationship between client and server components. The processing location is the core matter that is traded off in the various systems, hence a server-side oriented system puts more load on the server while a client-side oriented system distributes the personalised processing load among the clients (Peng & Tsou 2003). The latter option is implemented with Plug-Ins and Java applets, and is commonly used when the client requires advance processing such as with high levels of visualisation (e.g. MultiGen-Paradigm 2004) or with professional WGIS, although some PPGIS have been implemented in this manner (Carver *et al.* 1998). The advantage of these systems is the ability to process complex data, increase the performance of the application and reduce computation time (Morley 2004 Pers. Comm.). Nowadays there are various alterations which introduce a synthesis between the client and the sever (Huang *et al.* 2001, Huang 2003, Murphy 2004).

Since this system is oriented towards the general public, the former design was chosen, i.e. minimise the client's processing and maximise the server load and accessibility. These would facilitate maximum usability (even by legacy computers available in the public domain) or in other words, the system would be technically an 'easy access system' (Peng & Tsou 2003). Preferably, the system would not require any downloads by the client, and through central system management will free the client from any responsibilities while using the system (the client will not be required to maintain any sort of system except for a Web browser). The platform independency of the system (which only requires a simple Web browser) will increase the potential usage. This lightweight client oriented system does not automatically reduce the system functionality since the increase in server power makes it possible to process heavy requests on the server side in a bearable time. Additionally, as a multi-gateway system, there is potentially a possibility to add on additional functionalities for 'thicker' clients accessing the system.

The downside of server-side oriented service is the heavy processing load on the server, time performance and possible limited functionality on the client side, depending on the hardware availability and the communication connections (Peng & Tsou 2003). Additionally, clients accessing the system through HTTP (without any 'cookies' etc.) result in a stateless communication, thus complicating the system for multi step functionalities.

An outline of the system architecture is seen in Figure 4-1. The architecture is of a three tier system (although the third sits within the second), placing only the rendering procedure onto the client.

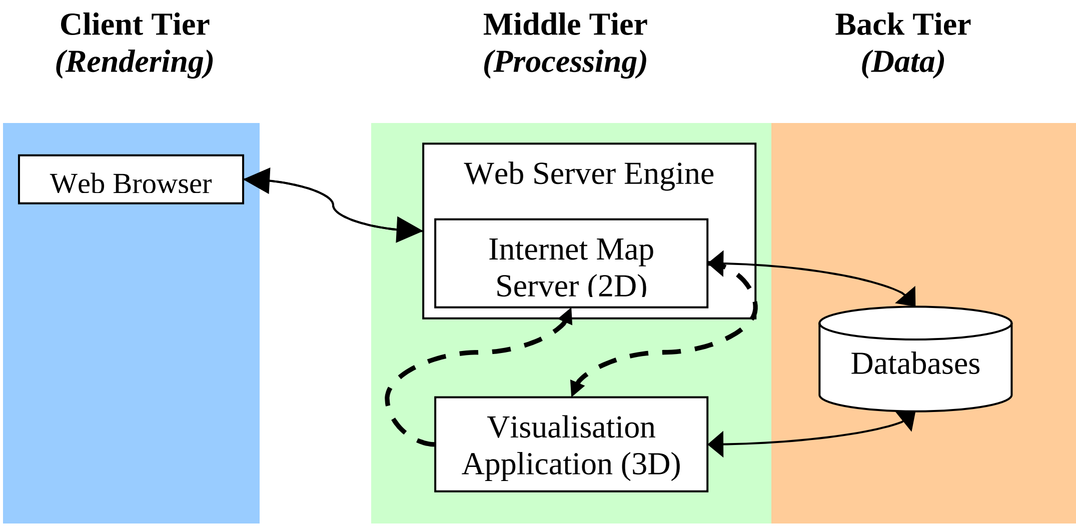

Figure 4-1 Proposed System Architecture for 2D / 3D interface.

The thin client is required only to render the Web pages, while the server processes and stores the data. The data is a separate tire but for practicality purposes it is located in the same machine. The CSI consists of passing information from the client to the Web server, rendering an image based on the received parameters and finally send back the rendered image to the client.

The Client-Server Interaction (CSI) includes fours steps. In order to explore the 3D environment in the client points at a 2D map, there after the server receives the relevant parameters passes a request to the visualisation application which generate an image (with the client's parameters in the database) that is finally sent back to the client. Table 4-1 introduces the communication in the CSI:

	Client	Interaction	Server
1	Get the Web page with map	→ ←	The HTTP communicates between the Web Browser and the Web Server. The server translates the request and send back the Web page
2	Point on map Input POV of camera	→	Read information from the Web server through the IMS and process (place parameters into the database and call the visualisation application.
3			The visualisation application does the following steps: Generate Map (with known datasets and parameters from the database) Set Camera Perform a snapshot Save image
4	Receive image	←	Send back image (through the HTTP)

Table 4-1 Client Server Interaction stages

1. The first CSI includes the HTTP Get command that is send from the client to server via the HTTP. Subsequently the server returns the appropriate Web page.

2. Thereafter the user sends the POV information and will Post it back to the server through an HTML form. The client's parameters are saved into a database and the visualisation application is called.
3. At this stage of the server would generate a link between the 2D base map and the 3D environment by executing a precompiled routine for generating the desired image by the visualisation application. The various parameters for the virtual 'camera' (POV) would be retrieved from the database. The visualisation application would obtain the view settings and export a 'snapshot' image of the environment.
4. Finally the server will send back the rendered image to be displayed next to the 2D Map

3D environment may be stimulating but does not always facilitate meaningful PP (this does not disregard the importance of attractiveness for the PP process). Referencing oneself in a 3D environment is awkward, subsequently the viewed object (the subject of the system) may get easily disoriented and hinder the public hearing in the PP process. A simple structured interaction (through a 2D map) "demystifies" the subject and environment.

There are currently three main frameworks available for communicating between web architecture components: Common Object Request Broker Architecture (CORBA), Java and DCOM & .NET. The decision to work with the latter option was based among others on Manifold's natural framework and the experience working with Microsoft programming language (.NET's creator) (see below). Originally the concept was to be demonstrated and implemented in a single software environment, which would encompass both an IMS and 3D visualisation functionalities. As this project attempts to provide a system to the public domain, the software should be affordable. Although GIS packages are constantly becoming cheaper, purchasing GIS software can still be costly. Manifold software was introduced as a low cost GIS software with significantly high functionality - hence suiting the project from the theoretical and practical points of views. For example, the basic software package includes an IMS and 3D visualisation capabilities and has abundant raster and vector functionalities (while the enterprise edition includes topology and multi-user support for slightly additional cost)[12]. This seemed to suit our scenario, since it is reasonable for a public body, wishing to implement such a system, to purchase a software with professional support, and not to rely on freeware community assistance. However after initial inquiries it was found that there is no possibility to programmatically control the 3D visualisation elements in Manifold. This forced an initiative to couple two GIS software applications. At this stage no other

[12] The cost for Manifold is between 245 – 400 US$, which is very cheap when compared to other GIS softwares (for example ESRI ArcGIS9 cost 1500 US$ and ArcIMS cost 1125 US$). (Prices as for August 2004)

GIS software was thought to replace Manifold since the data processing required a GIS software, which in our scenario would realistically be preformed in a low cost package. Additionally, the combination of an integrated IMS within a GIS software package seemed an attractive system to explore.

Similar to dynamic modelling there are three ways to operate the dual applications of the IMS and the visualisation tool: loosely coupled (no direct common platform), closely coupled (interact through a common platform) and tightly coupled (communicate directly) (Goodchild 2003, Huang *et al.* 2001). As in many coupling systems there is a debate as to the most appropriate manner to implement the coupling. Loosely coupled architecture manages the two systems by converting the input/output files of the two systems. The more closely coupled work in the same environment, directly exchanging files. In order to facilitate the communication between the components a framework needs to be set in place. Coupling two standalone softwares is referred to as *component-based* software development, which provides total autonomy to each software while still constrained under a set of rules (Gannon *et al.* 2002). ICT industry has moved towards application development using component-oriented software as part of interchangeable notion, which can be thought of taking Object-Oriented (OO) programming one step higher (Maguire 1999). The OO approach includes three characteristics: 1. Objects are instantiated from a general class, 2. Objects inherit properties and methods from higher classes and 3. Objects encapsulate methods that automatically come with the object. The autonomy of the objects allows for communication between various applications that were developed separately (by different people, at different times and in different programming languages). The usage of a cross platform programming languages like Java have the benefit of interacting with applications (and even more so with code libraries) in a convenient manner (e.g. Filippi & Bisgambiglia (2004) and Takatsuka (2004)). However the development of .NET environment (the successor of Component Object Model (COM) environment) extends the potential cross communication between various standalone applications (Baer *et al.*, 2002). .NET environments introduces a sophisticated run-time system which reduces the component responsibility for system maintenance (Ferguson 1990, Lüders 2004). .NET also sets foundation for future development of the UI, where the emphasis is on the client - thus the “UI support in ASP.NET centres around the server-side control model" [online] which would benefit the project (Shepherd 2003). Thus from all the above reasons, .NET and standalone visualisation software was introduced to couple with Manifold IMS, in a closely coupled manner.

The decision to use a database was based on several reasons: Firstly, for easy retrieval of data, in a natural and convenient place. Secondly, the attempt to couple two different software applications can be assisted using a common platform exchange, such as a mutually accessible database (e.g.

Access, SQL, mySQL). Finally the database is convenient to store various parameters and images for future referencing.

4.2 Coupling visualisation packages

During the first part of the project a prompt decision was required to decide on the appropriate visualisation software that would couple with the Manifold IMS. Personal communication with Kate Appleton (2004), a GIS visualisation researcher, stated that there is no known suitable package for such application, thus brief research was undertaken to explore the possibilities. Although there are many visualisation packages available (especially when taking into account the unsophisticated visualisation requirements of the system), there were several limitations that needed consideration, such as: programmatic control (access to object models and capability to customise the functionality), program language (usage of a language familiar to the developer) and the availability of the software (both in time and budget).

Several software visualisation applications where briefly evaluated as candidates for coupling with Manifold IMS. This was preformed under the limitation of time and availability. (For the entire list of reviewed software applications see Appendix 9.1)

1. GenesisII

   Genesis is a product form Geomantics company which has several products for visualisation, some of which are freeware. GenesisII has the basic capabilities to render a 3D terrain image, although the freeware does not have the ability to overly images on the terrain. Communicating with Kevin Woolley from Geomantics revealed their interest in our project and identified the main problem as the rendering time (Woolley 2004 Pers. Comm.). The product even has a free Plug-In software development kit (SDK), however the development would be supported in C++, an unfamiliar language to the author. Additionally, an assessment of the possible overall support foresaw difficulties (since the software was not acquainted in the GE department).

2. SiteBuilder 3D,

   MultiGen-Paradigm is one of the leading companies in the field of visualisation with products used for pilot simulators. SiteBuilder 3D is an extension to ESRI ‘s ArcGIS product, which allows the user to generate a 3D modelling in an easy an interactive manner from with in ArcGIS using the displayed data. MultiGen has a SDK, orientated towards sophisticated simulator products. Development in this environment would be very complicated (including hardware problems[13]), although the results would probably be very good, and since there was no available licensing in the available time this option was discarded. (MultiGen-Paradigm 2004)

3. Visual Nature Studio2

3D Nature Company has a series of visualisation software which include various packages of which the Visual Nature Studio (VNS) is directed towards the GIS visualisation community. The product has high visualisation capabilities and they concentrate their work on 3D landscapes. Regrettably, the software did not have customisation infrastructure and capabilities, and thus was abandoned at the early stages of the project (3D Nature 2004).

Two programmes where short-listed, Virtual Terrain Project (VTP) and ArcScene, and were extensively examined.

4.2.1 Virtual Terrain Project

VTP is an open source toolkit. VTP sets to “synergetic convergence of the fields of CAD, GIS, visual simulation, surveying and remote sensing” [online] (Discoe 2004). The toolkit has been developed in C++ and is distributed either in a binary format (for Windows) including a user interface, or as separate libraries**.** The toolkit is based on other libraries (such as OpenGL and wxWindow) and has a lively development community. Since VTP is developed as a toolkit it incorporates a great deal of flexibility, thus seemed potentially to accomplish the desired tasks. A binary installation of the software was experimented with and resulted in Figure 4-2.

[13] The server does not have the absolute minimum requirements of a 600 MHz Pentium III workstation

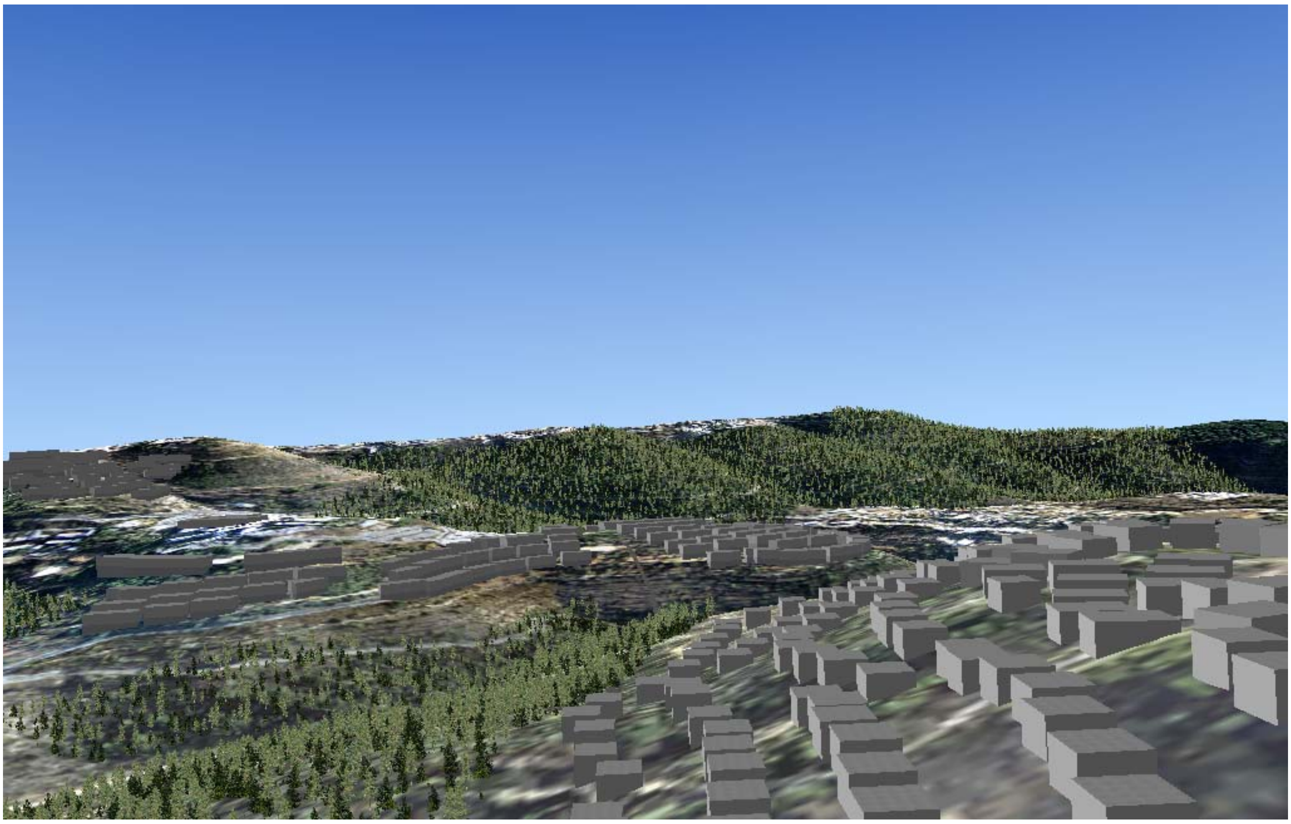

Figure 4-2 Screen shot from VTP

Experimenting with VTP generated some exciting scenes. The navigation within the software was smooth and the image rendering was a higher quality compared to ArcScene.

Unfortunately the system was developed on a C++ platform which is unfamiliar to the author. Additionally the initial experience with the software was tough[14]. Furthermore, although there is a supportive developer community, it was not certain what 'official' support was available especially when compared to commercial software, thus the following software was adopted.

4.2.2 ArcScene

ArcScene is part of ESRI ArcGIS8 suite[15] and handles 3D visualisation elements. The domination of ESRI in the GIS world led to many implementations with ESRI's product in the GIS and visualisation domain, thus was attractive for this project (Garret *et al.* 2003). The attempt to use ArcScene as rendering 3D software was based on the following reasoning. Firstly the author had prior knowledge and experience with this GIS visualisation package including some preliminary programming. Furthermore the author had some experience programming with Visual Basic, a common developing programming language for ArcObjects (the object framework that ArcGIS is composed of). ESRI also claimed to be fully compatible to Microsoft .NET development

[14] Approximately a week was needed to generate the first images.
[15] Which in ArcGIS9 has been implemented under ArcGlobe

environment (ESRI 2002), the chosen framework environment. Additionally, it was assumed that ESRI support system would assist in overcoming the predicted obstacles.
It should be noted that in the context of the WPPGIS scenario, the wide ESRI community establishment in the public domain upholds the possible scenario (although the software is considerably more expensive). User Interface

The UI is the system's façade that the clients interact within a PP process; the importance of such interface increases due to the vulnerability of the users actions. A simple and straightforward UI was designed to obtain from the client visualisation parameters (the positioning of the POV). The Interface will display three main elements: the 2D map, the 3D image and the view setting parameters. The 2D map should receive the central element, following that, the rendered image and finally the view settings parameters. The view settings should display the obtained parameters from the map, and allow for some customisation, such as for the height value of the POV. The display emphasis of the page, and of the over all Web site, should be as simple and attractive as possible. ESRI's *View Setting* dialog interface (Figure 4-3) displayed an initial idea for the display of information. The initial design thought to facilitate the drawing of an arrow representing the direction of the viewer. Trying to incorporate the target point (the point that is being observed) suggested to simplify the UI with an observe and target point (see section 5.4)

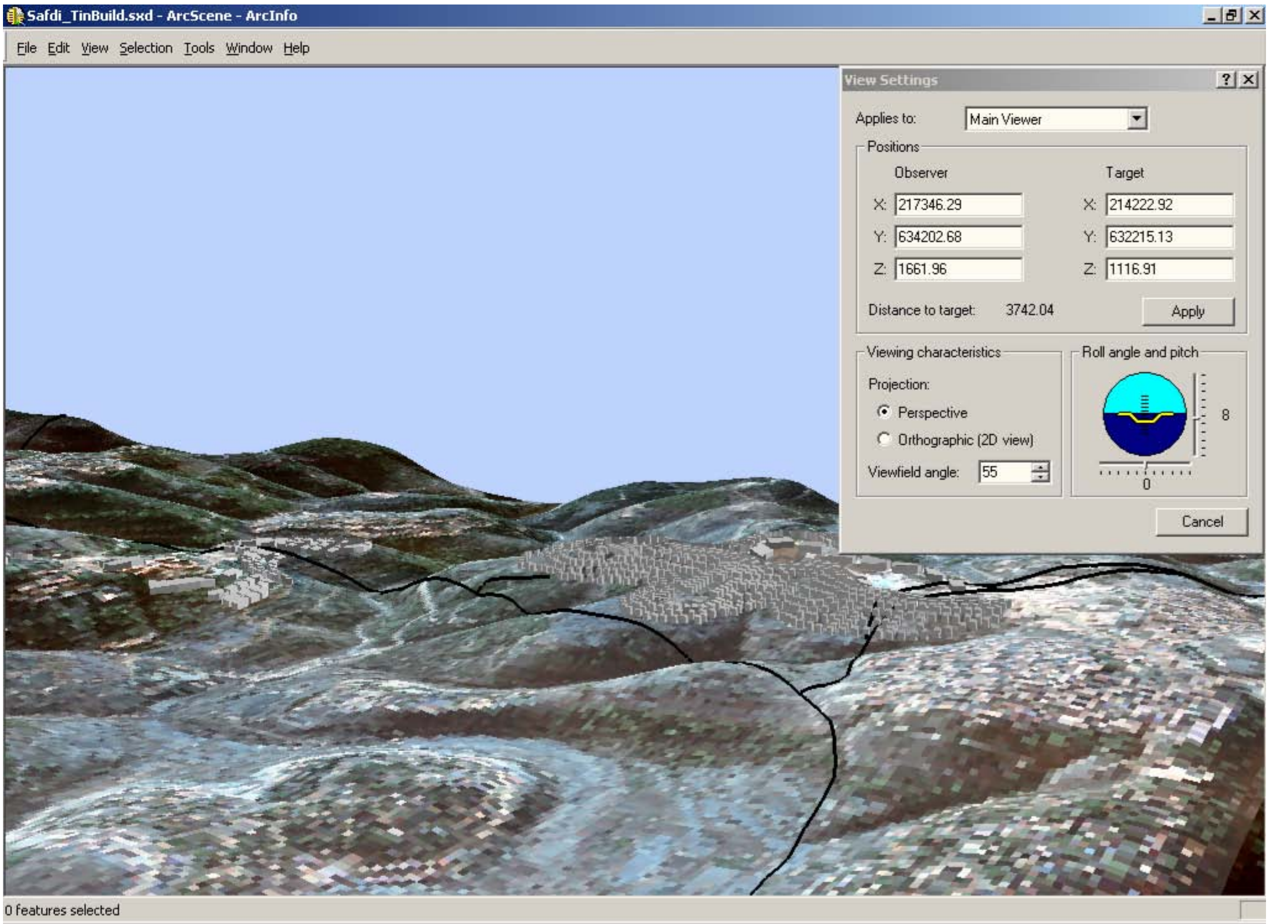

Figure 4-3 View Settings dialog window

The dialog displays the various parameters of the camera. Including the X, Y, Z coordinates of Observer and Target camera, various angles and the possibilities to switch between orthographic or perspective (3D) views. This gave a convenient outlook on the various available objects and functions.

A significant amount of research has been undertaken in the field of UI in IS and GIS and there acceptance by the public (for example Thong *et al.* 2002 and Haklay & Tobon 2003 respectively), however due to time constrains, limited development was available.

4.3 Hardware

The WPPGIS was developed on the hardware available at the time in the Geomatic department at UCL. The final server specification that was used was: Dell Precision 210, running on a Pentium III, 497MHz, Operating System (OS) of Microsoft Windows Server 2003, with 512 RAM. The Web server was Internet Information Services (IIS) 6.0 running on a compatible IIS 5.0 mode with approximately 40MB of data in the virtual directory. This was not an optimum hardware but what was available at the time of the development.

4.4 Data

The data that was used for the project was part of a Safdi project (Appendix 9.3), received from the Hebrew University, Jerusalem Israel and the Society for the Protection of Nature in Israel. The data consisted of a Digital Elevation Model (DEM) (from a 10 meter contours), orthophoto, proposed building footprints and roads.

All the data was processed in Manifold - simulating the usability of a low cost GIS software.
The DEM surface was produced from a 10-meter contour ESRI Shape (Shp) file, using the kriging method with 10 points. The orthophoto was used both in the 2D map and in the 3D rendering environment. The orthophoto sub-sampled from 0.5 meter resolution (600MB) to 5 meter resolution (15MB) with the bicubic method. This was preformed since there was no need for such detail in the 2D map in additional to the server's slow timing response. In the visualisation software the same orthophoto was used to speed the rendering time of the image.
The buildings footprints were extracted from DXF blueprints from the proposed development plans and the proposed roads were customised for display.
The project area was clipped from the larger extent of the Safdi project by calculating the viewshed analysis from the centre of one of the proposed neighbourhoods. This was done in ArcGIS surface extension, since this functionality was not available in Manifold 5.5 (but has since been introduced in Manifold 6.0.).
The virtual environment was built in ArcScene, using some customised add-ins. The orthophoto was draped onto the DEM, there after the building footprints where extruded. An attempt to insert the buildings into the DEM (as a TIN), using the *Adding Buildings to Tin* tool (ESRI 2001b), and then drape the orthophoto did not yield significant results. Using the add-in to generate 3D Building with an image façade improved only slightly the visualisation of the buildings (ESRI 2001a). Adding trees (with another ESRI tool, ESRI 2001c) to the environment brought the landscape to life, even if the result is slightly artificial.

5 Implementation

The project development was broken down into two stages: developing separate application in each software and then coupling both of the functionalities into one seamless application. The first stage was divided into two branches: implementing Manifold IMS serving 2D maps, and developing an ArcScene application to read information from a database and subsequently generate a rendered image.

Microsoft Development Environment 2003 with Visual Studio (VS) version 7.1.3088 and Microsoft .NET Framework 1.1 (Version 1.1.4322) were the programming environment, specifically Visual Basic .NET language was used. This environment incorporates extensive debugging tools, which would assist in the development. Deciding on a programming language was based on: 1. both softwares have significant support and examples in this language. 2. the author had prior experience in programming in the legacy language - Visual Basic.
Initially Manifold 5.5 Professional Version (SP1) was used which was upgraded during the project to Version Manifold 6.0

5.1 Manifold IMS

Publishing a map Web site from Manifold is a common process, which uses a built in function in Manifold software. The Web site was developed in Active Server Page (ASP) .NET as part of the decision to develop in .NET and VS environment. ASP is a technology that incorporates static Web pages (in the form of HTML) and dynamic / interactive capabilities using server and client side scripting codes. Manifold has a built in functionality to export and generate Web site in ASP.NET format, however this is only in a one-page format (i.e. the dynamic code is embedded with the HTML design code into one Web page file). Since the Website was oriented towards the general public, the usage of a *code behind* Web architect was thought to be appropriate, which allows for separate development of the graphical UI and the running dynamic code. Additionally, VS environment encourages the development of Web pages in this format. The development of the IMS included: designing a 2D map, publishing the map onto the Web and adding functionality to the Web site.
A simple 2D map was generated by overlaying an orthophoto on the DEM. Both were customised (e.g. opacity, shading) to obtain an attractive image. Thereafter, the buildings and roads (with labelling) were overlaid. Two vector point layers, corresponding to the observation and target POV, were introduced and linked to the database. The points were symbolised in an extravagant manner to enhance the visibility, each point was labelled with an ID number (which facilitated future

development for choosing a POV from several displayed). The system used a Microsoft Access database to store the POV. Although Access is a very basic database, since it has been widely implemented with the proposed software applications and the simple functionality requirements, it was thought to be the appropriate choice. Each POV was stored in a record containing three different fields: X, Y and Z coordinates. This seemed to be the simplest way to store the POV which would be read subsequently by the visualisation software. The possibility of using a Geodatabased (with point shape objects) might have been useful for transferring the POV as Points objects into ArcScene (to be directly incorporated into the camera setting), but Manifold was initially not able to read/write such format (this has changed in Manifold 6.0). Publishing the map onto the Web was by using Manifold Export functionality, which facilitated the option to export to an ASP.NET page format.

The Web site development included adaptation of the original ASP.NET *code* into *code behind* format, incorporating the connection of the database to insert the POV coordinates and to query the DEM surface to receive the height value at the inserted POV.

Transforming the Web page to a *code behind* format was adapted from a sample code by Khalid Pal[16], which required understanding of the ASP.NET *code behind* structure, some JavaScript in addition to Manifold Web format. The next stage was adding the functionality for inserting a POV by a Web user into a database. Using an example given by Manifold[17], the functionality was added into the ASP.NET environment. Developing the code for retrieving the height of a POV turned out to be time consuming even though there was assistance available from the Georeference Web site (Georeference 2004) (see attached disk for code).

This was the author's first experience with ASP.NET, thus a significant learning curve was encountered while developing the site in this environment. Usage of basic programming books (Aitken 2002a) and various Web resources (especially Manifold system user group Web site (Georeference 2004)) complemented the learning process. Additionally, since this was the first interaction of the author with IIS, a considerable amount of time was necessary to configure the Web site. Permission issues (in Windows OS and IIS) for the various files were thorny and required careful attention (this tricky issue was also noted among several experienced Manifold community developers). Although Manifold documentation emphasises the permission requirements, it was not oriented towards new IIS users, and some of the system debugging messages did not allude the permission problem, leading to setbacks in the debugging. During the development, Manifold was

[16] A download code from the Georeference web site, http://www.georeference.org/Forums/boxx/download.asp?Cat=18 [last accessed 13/08/2004]

[17] "Location" example from Manifold free stuff, http://www.manifold.NET/products/freestuff.html [last accessed 13/08/2004]

upgraded to a new version, which incorporated various improvements but resulted in considerable time resource allocation.

5.2 ArcScene

There are various possibilities to introduce ArcScene as standalone visualisation software, some of which were experimented below. Specifically, these were manipulations of ArcObjects and using an ActiveX Control. In order to work with ArcGIS in a .NET environment ESRI designated developers kit for .NET, however the installation disclosed a bug in relation to VS version 7.1 which required using an exe editor to fix the installation (Ligtendag 2003).

ESRI have some downloads that illustrate some functionalities of ArcScene, which provided some background for the development. An example to a “2D to 3D viewer” is the *ArcMap 3D Viewer (8.3)* (Carmichael 2004) which displays an ArcScene ActiveX control in a new window with clipped the data in the map view (Figure 4-4). Although this creates a link between the 2D and the 3D view, the user is still required to handle the troublesome manoeuvring in the 3D environment.

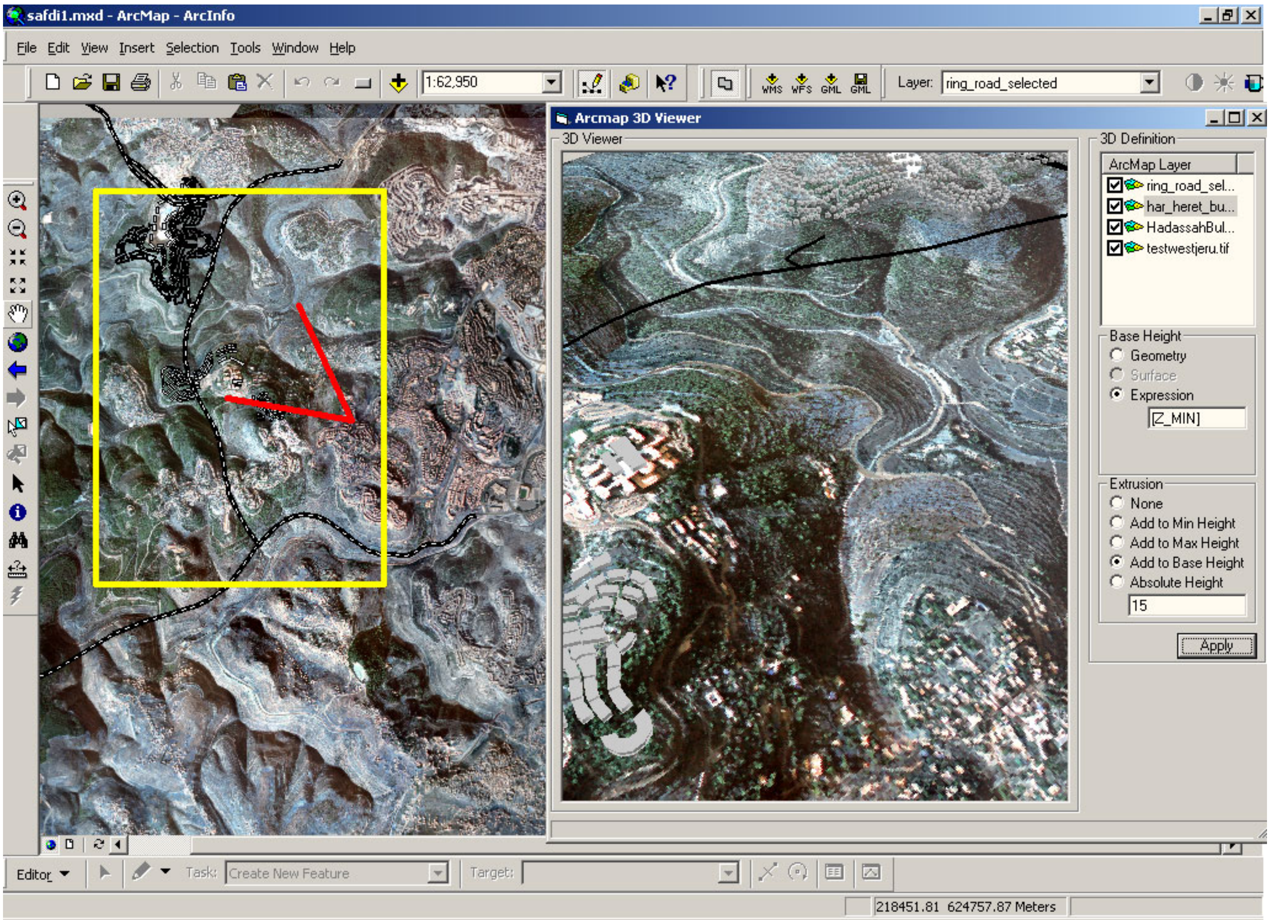

Figure 4-4 ArcMap add-in 3D viewer by Carmichael

The user defines an area of interest (yellow box), which then pops up an ArcScene ActiveX control with loaded layers clipped to the extent of the area of interest. The user is required to manoeuvre through the 3D environment with the usage of the mouse (which updates the red V angle).

ArcScene 'ViewSetting' example displays a UI with the ISceneView camera parameters (Figure 4-3) while the FlyByDemo[18] demonstrates the procedures to take a snapshot of the scene view. ArcObjects are the core components that constitute ArcGIS applications, including 3D analyst extension (which incorporates ArcScene). Understanding the structure of ArcObjects and the parameters and relationships of the scene camera was essential for the application. ESRI's support site, examples and add-in were very helpful and seemed to be very promising in the capability to perform the desired task.

The initial system architecture design attempted to instantiate a Scene class without running it in a window application. This would be an effective way to execute the application from the Web site,

[18] there are several code examples that describe the usage of a Scene camera especially the ViewSetting and the Flyby demo form ESRI developers site[online]: http://arcobjectsonline.esri.com/default.asp?URL=/ArcObjectsOnline/Samples/3D%20Analyst/3D%20Visualization/View%20Settings/View%20Settings.htm http://arcobjectsonline.esri.com/samples/3D%20Analyst/3D%20Visualization/FlyBy/frmFlyByProps.htm [Accessed 13 Aug. 2004]

since only the required elements for generating a scene (and image) would be requested from the system, without any of the Graphical UI (GUI) and other unessential components. After a short development in VB, Applications Edition (VBA) environment, getting acquainted with the various classes and attributes of ArcObject, the development environment moved to VS VB (and shortly after to VB.NET) to simulate the standalone environment in which the application would be executed. Once the application would successfully be executed, it could be exported as an Assembly (dll file) to be integrated into the Web application environment.

The application development required obtaining reference to a *Scene* coclass object (which would load the required layers to generate the modelled environment). The active S*ceneView* object, which can be accessed through the *SceneGraph* obtained from the *Scene*, is the reference that connects to a Window object containing the virtual 3D model. The *Camera* is the virtual POV positioned in the 3D environment which composes the virtual scene perspective and encompasses the properties and methods for the setting /modification of the POV positioning. An enquiry at the early stages of the project revealed that there has not been any attempt to use ArcScene in the proposed manner, as a standalone visualisation software running solely from ArcObjects. However there have been similar attempts to manipulate ArcObjects to generate ArcMap elements (Grossman 2004). A considerable amount of time was invested to exhaust the possibility to develop the application in this manner, since it appeared to be the most appropriate way to implement the application. Unfortunately, after much inquiry and trial and error this option seemed to be impossible, mainly due to the impossible capability of creating a windowless Sxdocument (ArcScene's file type) or Scene object. ESRI's support staff later on confirmed this "... we are not aware of any method to generate a scene image without instantiating ArcScene in a window."(Alston 2004 Pers. Comm.).

While deploying the above method an alternative approach was introduced, using an ActiveX SceneViewer control embedded into the Web page. Once the control was referenced to an existing sxd file, the user could not only view images but also interactively navigate inside the 3D environment. However this option was not permissible since the SceneViewer ActiveX control is a client side control, hence there is no possibility to interact with the embedded methods and properties and to programmatically manipulate the control (see section 5.3) (Microsoft 2003).

The final approach for developing the application was to interact with a fully ArcScene application running in an activated window. Once there was a connection with the file, the access to the various classes was straightforward. An advantage of this approach is the easiness of assembling the layers and features into the desired scene, since the Sxd file retains all the relationships and configurations between the incorporated layers. Obtaining the Sxd file was through the GetObject method, which calls a specific Sxd file. If the file is closed then the application is executed and runs in a new window, otherwise, when the file is already open it just hooks up to the appropriate window. The first stage of the development was to populate the camera parameters in the SceneView from the Access database. This simulated the procedure following the Web application, to obtain the camera parameters from the newly inserted POV (using the 2D map). A simple ActiveX Data Objects (ADO) connection allowed the application to link to the Access database. Once the application was able to read the new coordinates, the update of the Scene with the new Camera parameters was straightforward. The Camera has several properties, however only two were required to change the POV (and the scene): the Observer and the Target points (each consists of a geometric Point updated with X, Y coordinates and Z attribute). Lastly, the application needed to generate a new image from the updated Scene (implementing the Redraw method). ESRI's SceneView object comes with two intrinsic methods to take a screenshot of the scene or a shot of the Scene window with any other superimposed windows, they are GetScreenShot and GetSnapShot[19] respectively. In order to implement these procedures the function gets hold of the Window handle (which in .NET environment is of a System.IntPtr component) and then set the window to be the top most window, thereafter the image rendering function is called. Both implementations failed throwing exceptions of unspecified errors. The possibility to use the ArcScene Export2D method was not viable since this executes the Export2D window dialog box, hanging the application (waiting for a response) until the dialog box is released (with a user intervention). Finally, the solution was to use Windows functionality to take a screen shot of the window (similar to the GetSnapShot method).

5.3 Coupling Applications

Coupling two software applications was the crucial element of the project, an interesting and challenging task. Working in the .NET, environment facilitated various possibilities for the software coupling. As mentioned, a strategic decision was made to develop the application in a .NET environment, which was supported and encouraged by both software vendors. Manifold declare that "…Manifold 6.00 release […] uses **Microsoft .NET Framework 1.10** for maximum compatibility with the latest Microsoft technologies" (source bold) (Manifold 2004b). ESRI introduced Add-ins for VS to automate some developing tasks within ESRI's ArcObject environment as well as for deploying debugging tools. Initial inquires could not reveal any obvious manner to couple the software, thus (as mentioned) an attempt to use an ActiveX component was investigated.

[19] ESRI developers Guide (2001) [online]. Available from: http://arcobjectsonline.esri.com/default.asp?URL=/ArcObjectsOnline/ComponentHelp/esri3DExt/ISceneViewer.htm [Accessed 13 Aug 2004].

Both softwares have been developed in the legacy COM environment and renounce their successful migration to the .NET environment. The .NET environment allows usage of these legacy components by *wrapping* the COM object into a *managed code*. Microsoft .NET language executes code in Common Language Runtime (CLR) which is called a *managed code,* while COM code is was developed before CLR, thus is called *Unmanaged Code* (Gunderloy 2001). In order to work with *Unmanaged Code* the code must be wrapped by a *wrapper* to be able to execute in the CLR environment. Fortunately both Manifold and ESRI products are released with *wrappers*, thus are more easily integrated into the .NET environment by simply referencing their libraries in the VS project. This approach, using an ActiveX control, embeds a self-contained control (including properties and methods) onto a window form and creates a shortcut in the coupling architecture, allowing direct interaction with the Scene object. Unfortunately this approach cannot be embedded into a Web form for the aforementioned reason (section 5.2). Additionally, there is a severe constrain on the system, forcing the clients to install an ArcGIS component[20] to be able to view the image, an impracticable constraint[21]. Furthermore, the server time performance, while distributing the ActiveX control, is a considerable setback.

The final attempt to couple the software, was after ArcScene successfully generated a scene image with updated coordinates. Taking benefit of the .NET environment the project was stripped from its temporary window form and exported as a *ChangeScene* Assembly (in dll format) to be integrated into the Web project. The dll, which encompasses the newly object, was placed into the bin folder of the Web application and additional references (ESRI components) where set in the project. Once integrated, the dll was executed by a button control. The code generates a new object from the referenced dll object class, and then carries out the sub routine (which incorporates all the required functionalities). Unfortunately, at the stage that the object gets references to ArcScene object the application throws an exception (The exact code works perfectly in the Window application).

```
Dim pSxDoc As ESRI.ArcObjects.Sx.ISxDocument
'get the sxd file
pSxDoc = GetObject(sSXDFilename)
```

Error:

```
Object reference not set to an instance of an object.
```

[20] This component would probably not be free since the free ArcReader application does not have capabilities to view ArcScene files.
[21] Another possibility is to run the application on MapObjectIMS or ArcIMs – again not relevant in our case.

The cause of this error may be with the problems registering ArcGIS components with the system since the Web application successfully creates the *ChangeScene* object (created in VS) and also successfully manages to reference the object to a UID (to obtain the status of the existing licensing for ESRI's 3D analyst). However, slightly refining the above, all of ESRI add-ins seems to be installed correctly and ESRI's libraries have directly been referenced into the project.

Up to the end of the project this error could not be resolved.

5.4 User Interface

As a public oriented project, the UI was thought to be clear with simple functionality. The UI was designed with Macromedia Dreamweaver MX 2004, using ASP.NET files. Since the Web site implemented *code behind* architecture, it was painless to import the aspx file from VS.NET, design the Website, and thereafter import the file back to the Web application. The Web map page consisted of three main components: 2D map, corresponding parameters and the rendered image (Figure 4-5).

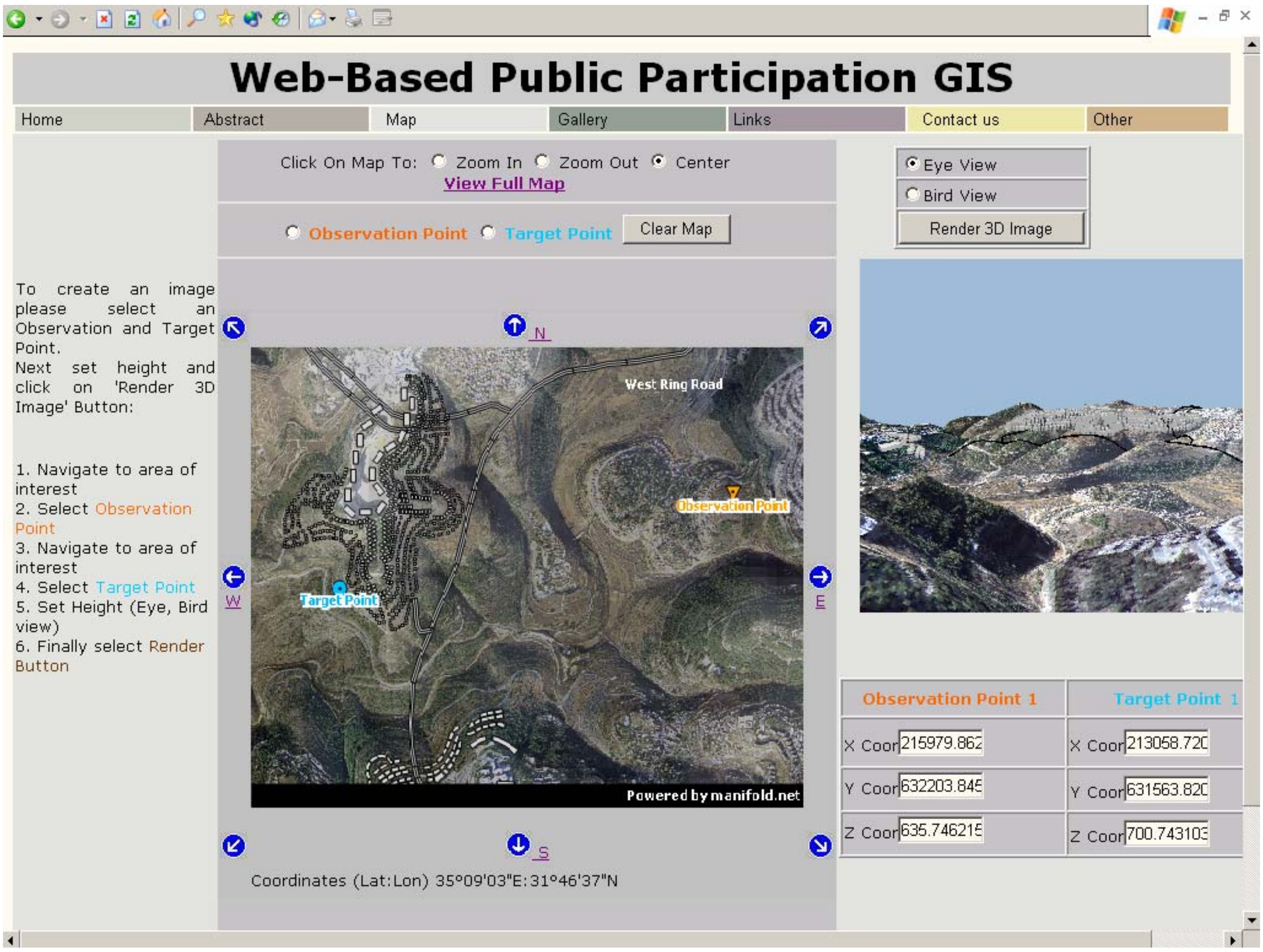

Figure 4-5 The WPPGIS User Interface

The UI consists of (from left to right) short instructions; navigation tools and 2D map, render button, rendered image and coordinates information. The centre of the UI incorporates the 2D map, with the various map functions displayed on top (zoom, centre, insert new POV). On the right hand side the outcome rendered image is presented. To keep the system simple, at any given time only one observation point and Target points are present.

The user interaction with the 2D map is a key issue in this project, since it is the essence of the concept. Setting aside the technical elements, the basis for a successful 2D interface to a 3D environment is in the usage of the system by the public via the interface. The initial concept for the interface was of an arrow that would be marked by the user, representing the direction and origin/target POV. However, as a first implementation of the UI it consisted of the user clicking twice on the map, first for the origin POV and secondly for the target POV. Although very basic, this gives the user a simple understanding of the required procedure, ('I'm looking from the observation point towards the target point'). Additionally this system sets the minimum parameters (X, Y coordinates and Z height) to generate the image without too much complication for the user. Germs *et al.* (1999) describes a system with three different views that permit the user with some manipulation abilities through a: Plan view (2D), Model view (bird view) and a Worldview (eye view). Similarly the height of the POV can be customised. The default height is received from the

DEM at the coordinate location of the POV (Eye View). A possibility to modify the height is by selecting the Bird View radio button, resulting in the increase height of the Observe POV (by 150 m[22]). This provides the user with some flexibility while still keeping the system very simple to the use by the general public. The *Clear Map* button resets the map and clears all the points on the map, while the *Generate Image* button calls the rendering function. The user would generate the desired POV and then click on the Generate Map button to create a rendered image.

An alternative user interaction enables the user to select an Observation POV and Target POV from the numerous displayed points on the map (for example with a list box populated by the ID numbers of the points). This provides the user with some additional functionality, but incorporates some additional complications in the procedure (this option was not fully completed see Appendix 9.4).

The final development of the system did not succeed in smoothly coupling both components of the system. On the one hand the user can interact with the 2D map and generate various POV which are stored in the Access database. On the other hand, a Window application can call the ArcScene object, set the scene with the users POV and generate the rendered image (this application can not be called from with in the Web application). Finally the image can manually be displayed on the Web. Hence the integration of both sides has not been completed.

[22] This value was based on the system calibration

6 Discussion

During this project, several noteworthy issues were examined which can be attributed both to the theoretical and practical elements of WPPGIS. The concept for this project was to introduce a 2D interface to a 3D environment in a WPPGIS. The literature review confirmed the theoretical usage of Internet within PP and GIS, and highlighted the problematic usage and interaction of these systems by the public (let alone issues of exclusion such as ‘Digital Divide’). The discussion can be divided into: issues concerning the general system and coupling environment and issues regarding specific usage of the software.

6.1 Coupling Applications

The decision on a server side system was performed as a service to the public, which restricted the development in some elements (i.e. ActiveX control), but appeared to be accomplishable. This is emphasised in contrast to the many 3D Web system that require some sort of contribution by the client (e.g. Plug-Ins, Hudson-Smith & Evans 2004, Kingston 2002). However the assumption for this architecture design is a strong server, which was not the case in this project - a fact that hindered the development. This service may be unnecessary in the future due to the abundant commercial web application that incorporates various Plug – Ins (e.g. Java and Flash) thus raising the *de facto* standard. Furthermore, the practicality of multi users accessing the system simultaneously needs to be examined (although the introduction of Grid computing opens new possibilities).

The system was initially intended to be implemented in a single software environment; however the inability of the software to implement such a system led to the introduction of the coupling of an IMS and a visualisation software. The project encountered several problems while attempting to combine two different software packages between two environments (Internet and Windows desktop). This is even with seemingly simple functionality. Combining the different technologies, Internet and GIS (or rather 3D visualisation), from within separate software requires a broad understanding of all elements. *Component GIS* advocates since the late 1990’s, for “effortless” integration between various software/system components. This is proclaimed by various software vendors (e.g. Spatial Tech Consultant Limited 2004, ZhaoXi 2004) and has been widely implemented in a local environment (e.g. Di Ludzio *et al.* 2004, Ungerer & Goodchild 2002, Painho & Cabral 1999) and in Internet environment (commonly as a three tier architect) (e.g.Vatsavai *et al.* 2000). However, no implementation combined separate IMS, GIS software and a database. The requirement to grasp each object model components in addition to the communication framework environment had a steep learning curve and implies high barriers for casual implementation of customised systems. The programming experience of someone with the author's background (some practical experience and the material from the Master course) seemed to fall short of that necessary to ensure successful implementation. When considering the context of WPPGIS, the successful implementation of such a successful customised WGIS will require significant expertise suggesting that, at present, its existence in the public domain will be limited. This coincides with Sieber (2003) findings regarding the crucial element of the capacity in an organisation (technically and nontechnically) to implement a successful PPGIS

As a geomatic professional, the importance of understanding the Internet environment was crucial for a successful system development. With the intense emergence of the Web into any scientific domain, especially the GI science, this requirement is most likely to increase.

The Internet introduced a common platform allowing various applications to interact through a common protocol (commonly the HTTP). As indicated in section 4, component-oriented software and .NET applications introduced new capabilities to software and system development. The strategic decision to work in a .NET environment incorporated both benefits and obstacles. Although the system requirements may have not required this environment, .NET introduced flexibility in the system development. This was experienced in the overall development independency of the different system component as well as with the Web designing. This was also exhibited with the failure to implement ESRI's screen shot method (in ArcObjects), thus requiring taking advantage of Windows environment. Furthermore, working in this environment increases the potential expansion of the system by other partners in addition to the support of independent software updates (Charlton 2004). Nevertheless, choosing .NET environment raised the complexity (a steep learning curve) and numerous challenges (in the coupling stage), which in the limited project time may have hindered more then contributed to the overall completion of the project. The fatal fault in the system coupling was a technical one (and not theoretical[23]) and can most likely be linked to the registration of ESRI's *wrapped* COM objects in the .NET environment or to various security permissions in the IIS environment.

The usage of a database was not required for the current implementation of the system, since once the Web application could communicate with the rendering application, it could have passed directly the set of required parameters. However the database set grounds for future development which may increase the user flexibility by facilitating the reselection of POV. It also permitted for the existing loosely coupled system, transferring the users parameters form the IMS to the

[23] This does not exclude the possibilities for choosing a better software for such a system.

visualisation application. Additionally, the database can archive the rendered images to be displayed for future public intercourse.

The experience implementing the system onto a server required special attention, that initially was not taken enough into consideration. Throughout the project several obstacles emerged relating to usage of IIS, especially regarding various permissions, which may have had (as mentioned above) crucial influence on the system.

6.2 Software

Working with Manifold proved to be accessible and up taken after a reasonable learning curve (approximately a week). Special attention was required to the understanding of the coordinate system management, which also arised when implementing the IMS application. Although this was the first acquaintance with the software, the help documentation[24] and community support led to a high level of data processing. The vast amount of functionalities allowed processing nearly all the data in the basic software package, a valuable parameter when considering the context of the software usage in the parsimonious public domain. Implementing the basic Web map site from Manifold was a simple task (that was only complicated from the IIS aspect) and when compared to other map servers, such as IONIC RedSpider Web application (2004), it is considerably simpler (setting aside the different IMS capabilities). Adding functionalities to the map server requires significant programming skills, which in the context of WPPGIS requires additional thought when considering initiating a public system.

The choice to work with ArcScene was strongly influenced by the availability of the software at the time of the project, and the attractiveness to work with a leading software package in addition to the author's previous experience with this package. Development in ArcScene requires a comprehensive understanding of ArcObject 3D analyst extension. Although ArcScene comes with a complete object model, the user community appears to think that ESRI has not given much thought to development in this environment (e.g. Ralston 2003). ESRI's perception that "It is not common for developers to extend this [ArcScene] library." (P.83) [Authors addition] (ESRI, 2004) confirms the user community thoughts and may explain the various obstacles in developing in this

[24] For task comparison between ArcGIS and Manifold see the recent pager from Lembo, A. (2004) How Do I Do This in ArcGIS/Manifold?: Illustrating Classic GIS Tasks [online], http://dspace.library.cornell.edu/handle/1813/165?mode=full, Cornell university .

environment. ESRI's limited assistance was also surprising[25], especially when it is considered the world leading GIS vendor (particularly in the education domain). Nonetheless the extensive help documentation and samples considerably assisted in the development, but it came short of the requirements of this project, firstly in the incapability to develop the application solely in ArcObject and secondly in its complexity to be integrated into an external environment (see section 5.2). Designing a coupled system requires maximum control over the object components. Once the development is restricted to certain objects, i.e. requiring getting hold of a parent objects and then 'drilled down' (e.g. from an Application object down to the *SceneView* object), the development potency is reduced[26]. In addition, despite the fact that it may seem as a shortcut accessing pre-compiled components, the development inflexibility is critical (not to mention the failure to use ArcObject's Screen Shot method). Furthermore, the restrain to access ArcScene objects only from a running window application results with an ineffective system, exhausted memory resources and increased time performance. Working with separate source libraries, such as VTP, rather then binary distributed software, may provide higher level of control over the objects, which consequently may result in a more powerful application. While generating the visualisation environment, recurrent *crashes* of ArcScene resulted with minimal features. This troublesome issue was previously experienced by the author, which can be mitigated with strong computers. This occurred even though only a subset of the entire public campaign was visualised, and the orthophoto was sub-sampled (resulting with some granular imagery). This can also be attributed to the limited computer power, which in the context of PPGIS system is extremely relevant.

[25] " … Unfortunately, UK Support are unable to provide assistance with code development using ArcObjects, therefore we always suggest that users post a question on the ESRI Support Discussion Forum…" (Alston 2004 Pers. Comm.)
[26] This may change with the introduction of ArcEngine in ArcGIS 9.0

6.3 Limitations

This project was carried out as an MSc. dissertation, and as such had severe time restrictions which enforced a rapid assessment throughout the development. When relating to the implementation of the system some valuable insights were made, which go beyond the context of WPPGIS. Tangential issues to the coupling itself required considerable amount of time, this could be attributed to the sharp learning curve in several areas (.NET, IIS, Manifold etc.). Upgrading Manifold software in addition to the movement between server machines caused considerable time wastage. Transferring from VBA to VB 6 to VB.NET was overall trouble free, although required some time and adaptation.

Additionally the following limitations were identified as the key components influencing the system development.

- The decision to implement the visualisation elements with ArcScene eventually caused the implementation to work in an evasive manner[27]. Furthermore, using the software in the designed manner would probably breach the licensing received from ESRI, since using ArcObejcts in a Web application requires ArcServer licensing or some sort of special licensing[28]. From the scenario aspect, the basic software cost in addition to the required 3D extension (for ArcScene) and licenses decreases the likelihood to be implemented in a public community domain.
- An acute drawback in the development was the inability to display the system to the public, in order to receive feedback on the various developed elements (especially regarding the UI and the ease of functionality). This considerably limits the proof of concept, since there is a strong requirement to obtain verification both for the theoretical and practical elements.
- The system as displayed is limited to a single user, and is not configured for multi simultaneous users.
- Hardware - the system was developed on two computers with minimal memory and processing capabilities (e.g. only a Pentium III 497MHz with 512 RAM is very limiting when today commonly Pentium IV has several GHz and Giga RAM). This considerably influenced the time factor (very slow response), and some bugs where attributed to this factor. Furthermore Manifold states that it relays on increasing

[27] running in a stand alone Window

[28] If acquired, the system development within ArcIMS (ESRI's map server application) would probably be more appropriate.

amount of processing and memory, especially when relating to a server (Manifold 2004c).

- The development of the system on various computers in addition to installation and reinstallation (including upgrades) of software and OS exhausted the limited time resource. Additionally the essential requirement to upgrade the IMS may have been ultimately beneficial, but required adaptation and debugging of the system.
- The advantage of the system being a light client system assumes that the system is *stateless*, thus requires special attention when expanding the system (to a virtual society functionality). In order to allow for the users to experiment with the system and exchange ideas the system must be able to remember the actions and preferences of the user. The current system needs substantial development to incorporate such functionalities as a *statefull* system.
- Working in a Web environment should try and take benefit of the possibilities such as developing cascaded surfaces and possibly an Application Programme Interface[29].
- Visualisation of the 3D environment was very basic, only basic elements were added (e.g. trees). No available data for surrounding buildings was available to place the urban development into context with other buildings. Furthermore, additional details are essential for a successful uptake of the virtual environment by the public (Bishop & Rohrmann 2003). The visualisation quality of the virtual environment was also greatly affected by the limited computer capability (hardware) to work with high resolution orthophoto and graphical features.

[29] For an example Google has released an API beta service (http://www.google.com/apis/ [accessed 29, Aug 2004])

7 Conclusion

This project is a preliminary study providing a *proof of concept* for an alternative interface to 3D environments, specifically for the general public via the Internet. Carver (2003) suggests that future PPGIS research agendas should "research into methods of communicating GI (and associated issues) to the lay public; and more practical real-world application of participatory GIS …" (p.68). Additionally, displaying information in various formats for different stages in decision making processes is important for PP (Jankowski & Nyerges 2001). Accordingly, this WPPGIS provides a combination of views in an Internet environment to communicate spatial data to the public. Although the project did not manage to complete a fully functional system, it does set foundations for a future development both from the theoretical and practical element.

7.1 Future Developments

The project set the basic framework for a 2D interface to a 3D environment, thus leaving many features for future developments. A necessary step to implement this system is to succeed in coupling an IMS with a visualisation application. Additional features may include:

- Adapting the UI for convenient usage by the public. This must include, among others, refining the user interaction with the system (e.g. choosing various POV, deciding on a final image after a trial and error procedure). Multi cultural elements in Web interfaces are another dimension of multi-communication channels that need to be addressed (Marcus & Gould 2000).
- The system must be configured for multi threading operation, facilitating simultaneous usage of the system by a number of users (i.e. threading the requests).
- In order to increase the level of PP in the WPPGIS there is a necessity to develop a platform for a virtual society. One tool that could be implemented in this sense is a MapForum – a forum that permits users to share annotated images. After generating an image, the user would be able to annotate the image with personal comments, there after save the image to be referenced by other members of the community.
- The current system proposes a 'read only' functionality with the datasets, not permitting any manipulation with displayed features. In order to enhance PP to higher levels, a scenario modelling could be introduced, by facilitating the to manipulate the features by the public, either specifically (such as with the Germs *et al.* (1999) system) or in a global manner (as setting parameters for scenarios).

7.2 Summary

The theoretical background for this project is substantial, although this does not exempt a critical analysis of the theory implementation. Although there was no appraisal of the system by the public, the project was found to be potentially of great use for PP. Interactive 3D environments are difficult to engage, even from the author's experience, manoeuvring through 3D environment is always difficult (including. ArcScene and VTP). A simple function converting a customised 2D plan to a 3D view was implemented in various software desktop applications, but has not been found in the Internet environment. The experience to develop a *Component based* system revealed to be extremely problematic, and not as smooth as enthusiastically pronounced. This was especially experienced with the combination of the Internet environment. Thus suggesting continues expansion of out-of-the-box GIS functionalities with limited system customisation.

Diversity in nature is a crucial property in many aspects, and is a key feature in successful evolution. Similarly, the interaction between human beings requires non-conformist and open-minded perspectives. The dynamics between GIS and society will continue to be researched, and possible methods to liberate GIS from the perspective of a tool (*par-excellence*) to a common social media are required, or as Sui & Goodchild (2003) wrote (original emphasis):

> "The clear and present danger is not GIS or information technologies, but our blissful ignorance of the implications of what they are going to do *to* us, because we have concentrated too much on what GIS can do *for* us." (p. 14)

Development of public VR environment systems, such as CASA's Virtual London project (Hudson-Smith & Evans 2004), must take into account not only the possibilities to access these environments but the manner in which they do.

Finally, Fraser criticises Habermas for a single public sphere rather then multiple spheres (cited in (Aitken, 2002b)), in parallel WPPGIS must permit access to these three spheres: PP, GIS and Internet by featuring multiple gateways. A multi-gate interface to any system may cause some complexity but surely maximises the benefits to the end users. In a world enriched with possibilities, multi gateway systems are expected to expand, not only in WPPGIS but also in other GIS (van Deursen *et al.*, 2000) and IT systems.

8 References

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9 Appendices

9.1 Software Examples

There are many GIS and Visualisation software packages available, some are specific to a domain and others are more generic. During the initial stages of the projects several software were appraised as coupling candidates with Manifold IMS. Below are the additional software (to the listed in Chapter 4) that where reviewed.

1. SiteBuilder 3D
   CommunityViz Founded in 1995, was one of the first software applications oriented towards PP. it has been strategically coupled to ESRI products and works as an extension to ArcView and ArcGIS. The SiteBuilder allows for the development of a realistic view using data from with in ArcView. CommunityViz are a non-profit organization with the analysis/ decision making, scenario building and 3D visualisation tools. CommunityViz has various capabilities – one of which displays 2D and 3D side by side (Figure 9-1), a similar application to the desired application – but not in a Web environment.

   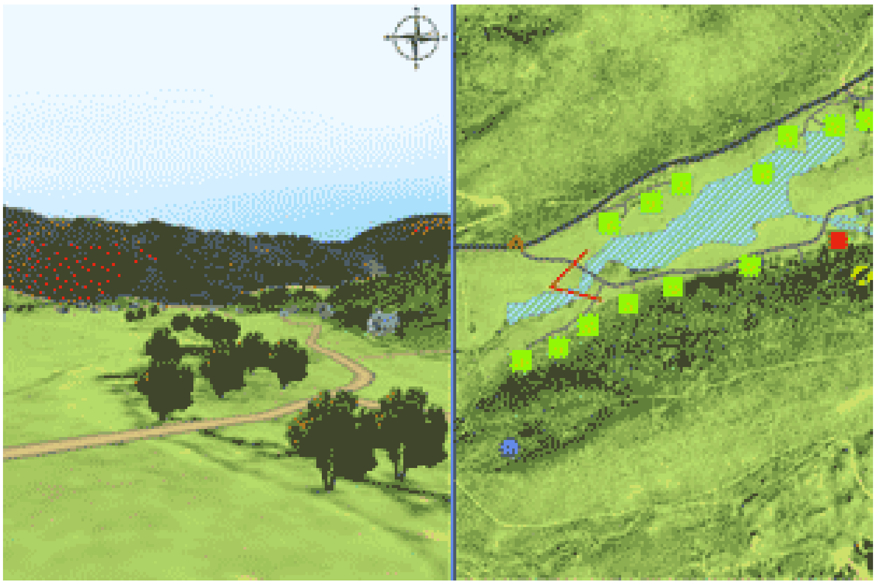

   Figure 9-1 CommunityViz views 3D and 2D side by side.

   Image source Smith (2004a)

   Although there clients are public bodies and community planners the software is considerable costly (2500US$).
   Web page: http://www.communityviz.com/
   A recent article on the software expands the various capabilities. Smith (2004a).

2. MultiGen-Paradigm - SiteBuilder 3D,
   MultiGen specialises in various products for VR, aiming to the high end of the market. These include flight simulation and VR for games. There Model Builder 3D enables building 3D environments from geographical datasets, while there SiteBuildier 3Doperates as an add-in for ESRI's ArcView 3.2 GIS software, allowing to generate a 3D environment from 2D Shapefiles. As mentioned the licensing and availability restricted the experimenting with this software

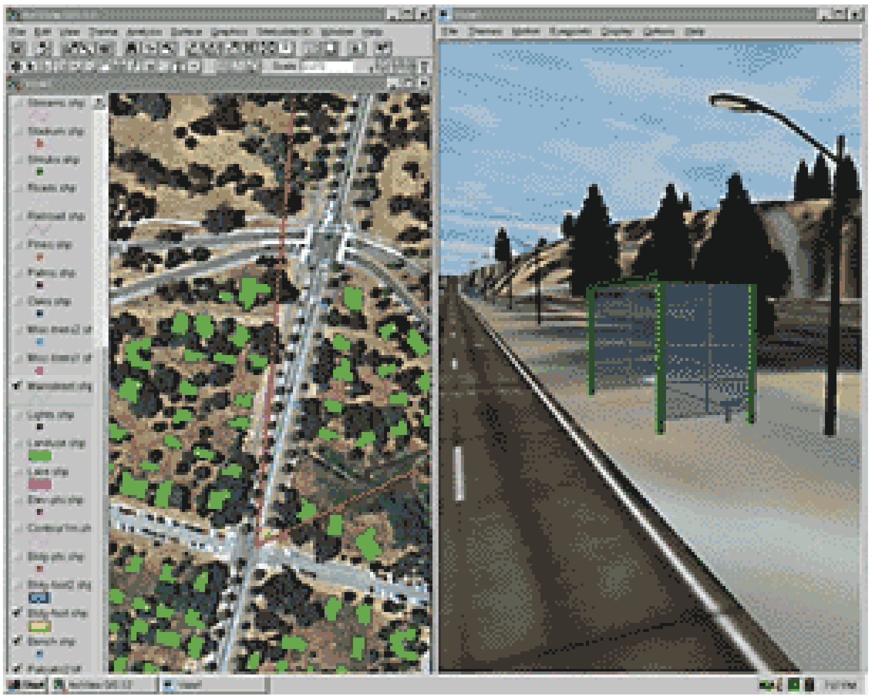

Figure 9-2 Screen shot of MultiGen StieBuilder 3D

Image source (MultiGen-Paradigm 2004)

3. Key to Virtual Insight - K2Vi
   K2Vi is a real-time interactive, 3D visualization virtual reality software platform which generates interactive 3D environments from a wide variety of data formats, especially ESRI formats. Currently there is a Plug-In to ArcMap ESRI, which allows to directly generating K2Vi project.
   The power of K2Vi is its ability to make changes to the virtual scene from within the scene, and then save those changes, hence for a combination of GIS capabilities in a VR environment. K2Vi includes pseudo 3-D images on a flat monitor screen, true 3-D glasses, the Virtual Workbench, and The Cave. This allows for multi-viewers to a set of spetial data. The K2Vi is a spin off of the Germs *et al* (1999)
   web site: http://www.k2vi.com/index.htm

9.2 WPPGIS examples and Sites

The following Web sites demonstrate the various trends and richness that WPPGIS incorporates.

1. One of the first WPPGIS is the Slaithwaite project. The usage of a interactive map facilitated the feedback of the public to the developing of the town.
   http://www.ccg.leeds.ac.uk/slaithwaite/ [Accessed 28 June 2004]
2. Castle (2004) strengthens the positive attitude by the public to PPGIS in his study 'Empowering disadvantaged and marginalised groups with in planning processes: Accessibly mapping though PPGIS'. This system facilitates community mapping of an accessibility map to Enfield Town via the Internet. The research is still in progress (Aug. 2004) – no ending date is available.
   http://www.casa.ucl.ac.uk/cjec/msc/index.htm [Accessed 28 June 2004]
3. Gudes *et al.*, (2004) present a WPPGIS for a process of planning a master plan for the "Shapira Neighborhood" in Tel-Aviv, Israel. The site is part of a general PP process to the development of the neighbourhood. The ArcIMS site is a 'read only'

site, and does not allow to integrate new features.
http://shapira.bgu.ac.il (in Hebrew) [Accessed 28 June 2004]

4. Jankowski & Stasik (1997a) developed a Spatial Understanding and Decision Support System (SUDSS). This system allowed the public to change the weighting of the various components in the decision making, thus facilitating high level of participation via the Web.
5. Integrated Approaches to Participatory Development (IAPAD) is an organisation promoting PPGIS in general including WPPGIS. This include sketch mapping an physical 3D community mapping that are integrated into GIS.
http://www.iapad.org / [Accessed 28 June 2004]

9.3 Urban Scenario – Safdi Project, Jerusalem Hills

Jerusalem city has a complex political historical background which greatly influenced its urban development. The current city plan dates back to the mid 1960's and during the past 5 years a new urban scheme is planned. During this period the city has grown immensely, not always confined to the urban scheme. During the past five years the Municipality has been trying to expand Jerusalem's boundaries westward in order to annex these proposed neighbourhoods and the new city, none of which have to date been approved by the relevant planning committees.
Most of the various social, urban and geopolitical arguments for the expansion, submitted by Jerusalem's Municipality have been rejected not only by the National Planning and Building Council, the authors of the National Outline Plan #35 and its steering committee, but also by experts employed in various planning and academic institutions (not to mention the lack of addressing major environmental questions).
As a result of the above environmental organisations have teamed up with social parties to question the need for this development and to propose alternative options. This raised a wide public campaign to pressure the municipality to rethink the proposed urban development and to incorporate a genuine public hearing in the future development of the town.
This campaign has began since 2001 and is constantly expanding.
For additional details see http://www.sustainable-jerusalem.org.il/jerusaleme/jerusaleme.html

9.4 *Alternative User Interface*

The development of an additional UI allowing the user to choose from multiple displayed POV. To the date of the submission this was not fully implemented. The image displays the several points, that can be reviewed in the parameter panel (bottom right).

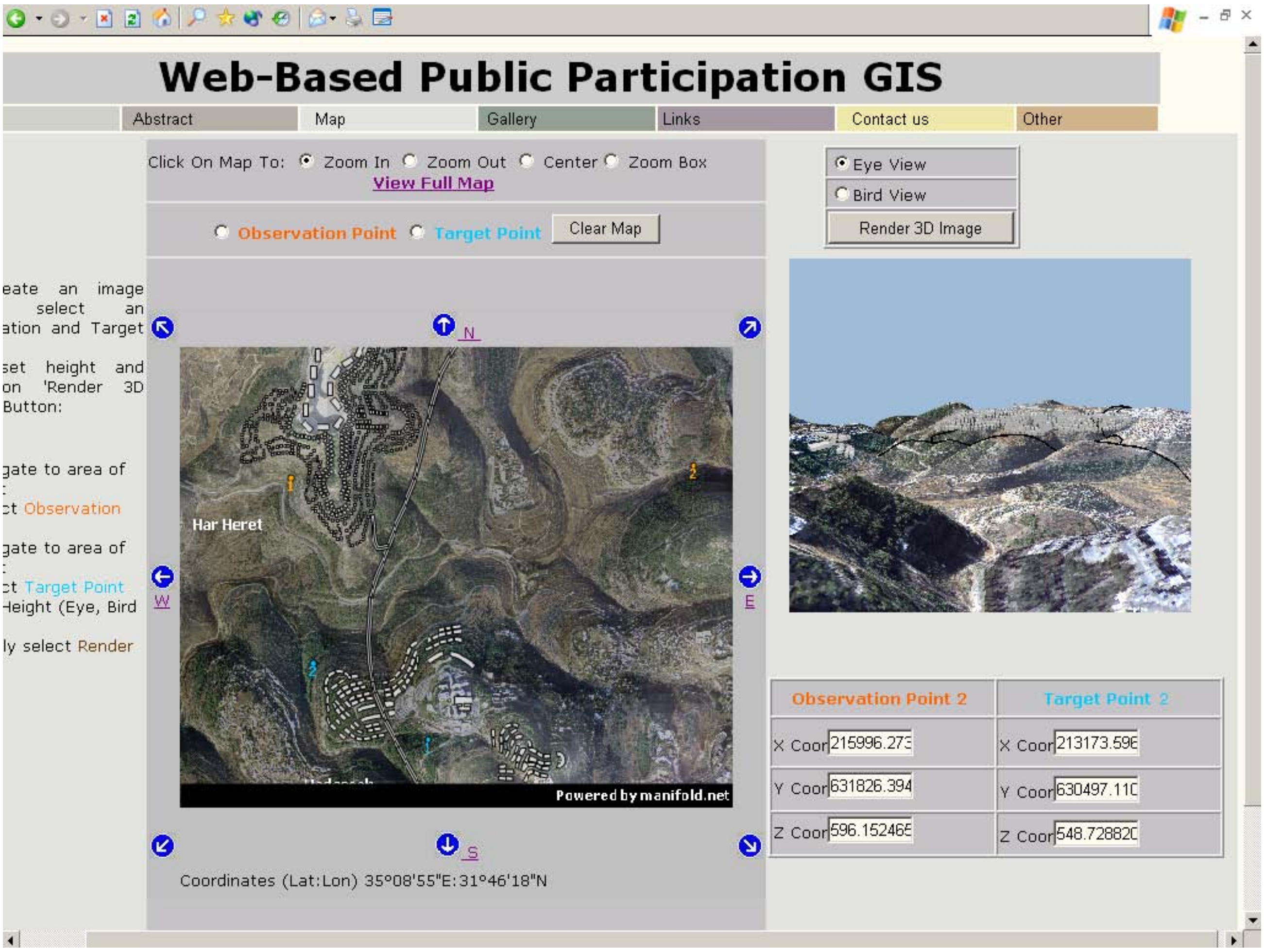

Figure 9-3 Alternative User interaction to the WPPGIS

9.5 Image Gallery

The following screen shots display the *Safdi* project virtual environment. This environment would be the basis for generating the user customised rendered image. The various images display the surrounding, the graphical features (buildings and trees) and the orthophoto surface (which is pixelised)

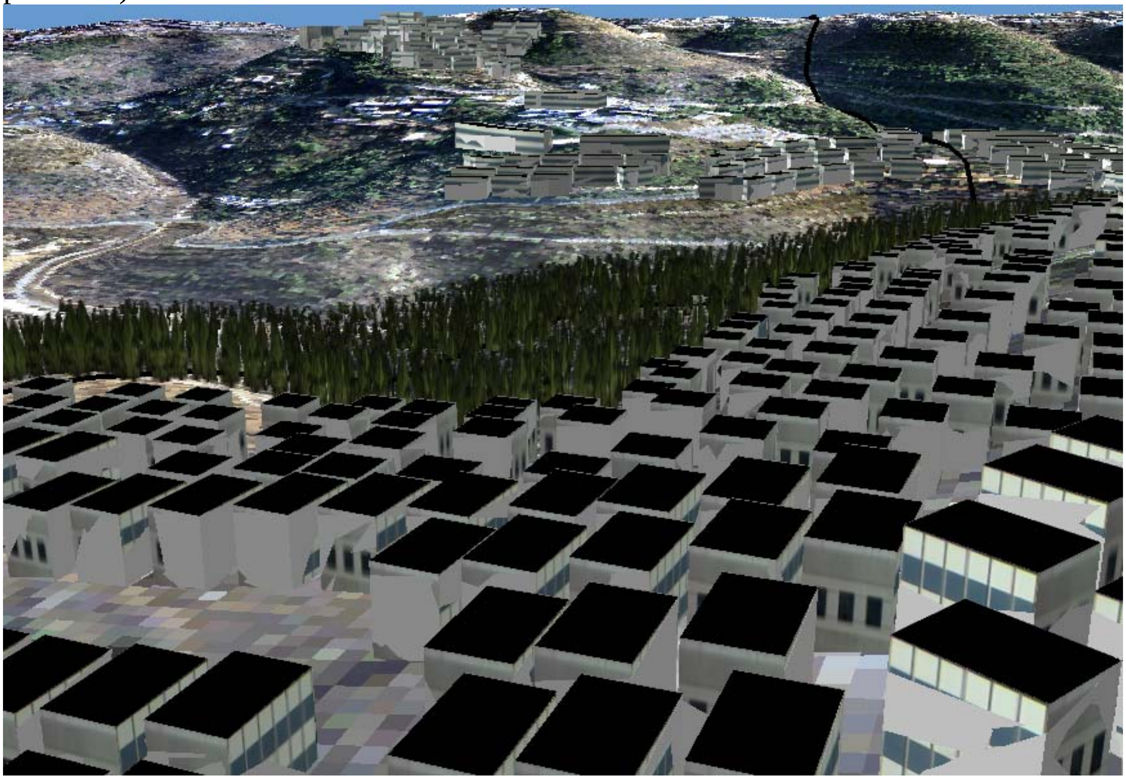

Figure 9-4 ArcScene Screenshot. Incorporating 3D buildings and trees.

View from HarHeret eastwards to Hadassah

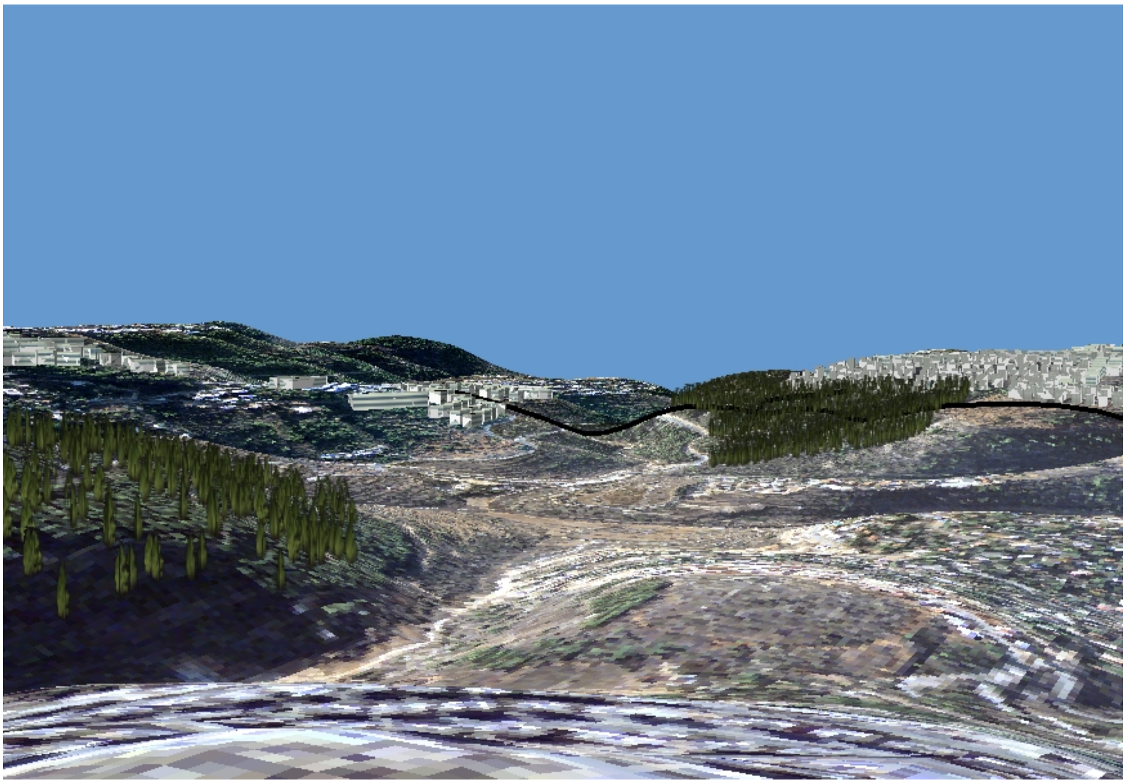

Figure 9-5 ArcScene Screen shot. Displaying the granular surface and featured trees

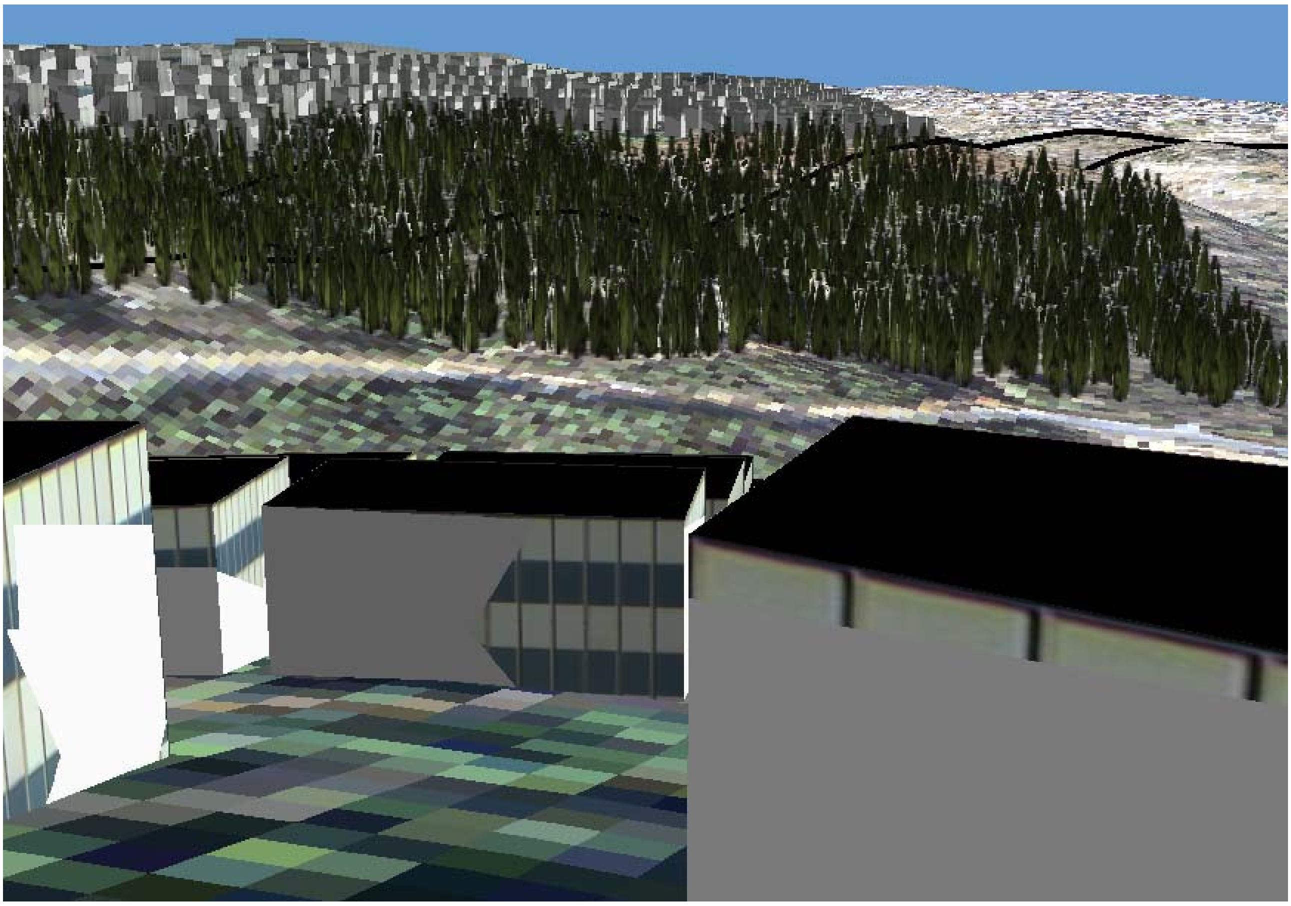

Figure 9-6 ArcScene screen shot, displaying ArcScene rendering façade capabilities.

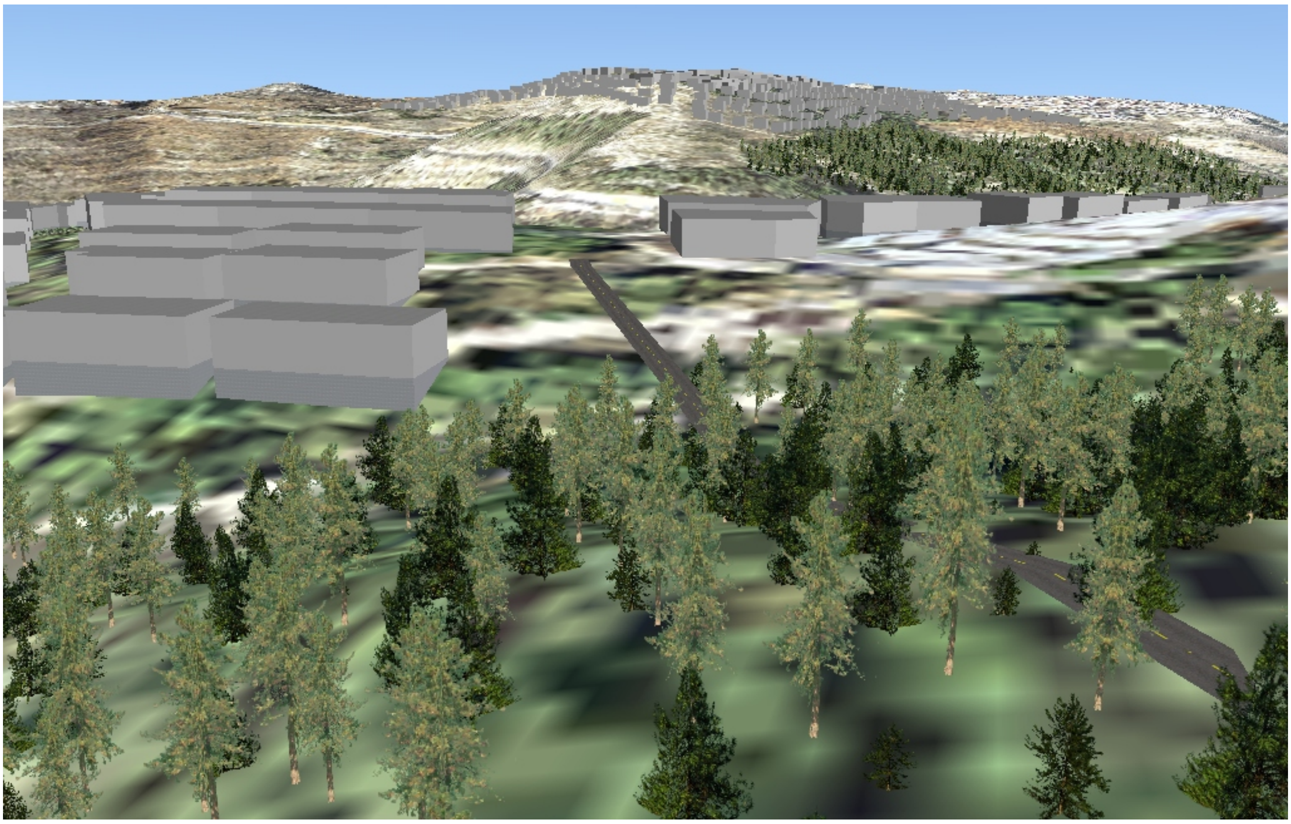

Figure 9-7 VTP screen shot,

the vegetation can be imported from an XML file while the building can be rendered with a similar façade as ArcScene