Chapter 1 Virtual Geographic Environments: A Primer

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Introduction

Virtual Geographic Environments (VGEs) are built on the foundations of geographic information systems (GIS) and geographic information science(GI Science) in which considerable attention is paid to the user in terms of the manner in which they interact with the software[1]. User interaction is thus a key component of such systems. They can range from systems designed for professional and scientific use where spatial analytic functions are dominant, all the way to systems which aim to popularize and disseminate information about various geographies to the public at large. Included in the spectrum of usage and users are systems that contain a blend of new functions for accessing and searching for information which have not been available hitherto through more traditional media. These are best seen in the proliferation of hand held devices, usually mobile in some sense, which are bringing entirely new modes of routine query and search to the casual user.

The degree to which users are immersed in such systems defines major differences between VGEs. Frequently these involve the media used to construct and access the virtual environment. Systems range from simple desktop interaction which are dominated by local or remote software whose access is through the screen display to entirely immersive systems in which the user and machine are interwoven with one another in intricate and often convoluted ways, engaging not only in visual but in audio and tactile interactions. The term virtual reality (VR) emerged in the 1980s as a shorthand for artificial environments in which the user was able to 'suspend belief' by accepting that such an environment was real. Full immersion of the user in such an environment was the starting point and this led to wearable computers in various guises but the term quickly became more generic with anything that involved users interacting with systems that mimicked the 'real' as being 'virtual' in some sense. In fact the media used to generate virtual environments has also broadened as the term has moved into more general use. Initially, literally embedding oneself in the hardware through wearable modes of interaction and thence to wrap-around displays such as CAVEs and VR theatres were regarded as being the modus operandi of VR. But thence came the Web. VR moved back to the desktop where virtual presence came to be established as much through online experiences as through any development of tele-presence involving stand-alone computers[2].

The key drivers of VGEs involve the extent to which such environments embody realism.

This of course turns on what we define as real or on what users consider to be an appropriate experience of a system that purports to embody the sort of realism necessary for their purpose. The particular virtual realities that preoccupy the contributions to this book involve many different kinds of media that in some way reflect the kind of geography that is built in GIS and GI Science[3]. This implies that the systems in question embody some sense of location and place which is analytically tractable. It may be that the users of such systems are not particularly interested or expert in the kinds of analysis that feature in such systems but such analysis is definitely necessary in the construction of such systems and is represented through its software. The VGEs we will present also involve a range of media although most involve the Web (or the Grid) as a means of delivering the virtual environment to the desktop, or more generally to the client from some remote source (or server/s). There are examples here of more traditional virtual environments such as those accessed through the VR theater or through various interactive immersive gaming but most do not involve anything other than users interacting with other users either in real environment (around the desktop) or across the web as, for example, in virtual worlds or virtual design studios. In fact, our rather general definitions of virtual reality and virtual environments suggest that these systems are more like 'augmented realities' in which the real and the virtual are mixed in different blends. Here users interact with each other in traditional real terms while engaging with others who are remotely connected to such environments, represented as avatars, for example, in virtual worlds or as simulated actors from models which engage with real users in actual settings or real users in imaginary worlds. A cornucopia of realities is suggested by this imagery.

To progress our primer, we will organize VGEs into four key areas, dealing in turn with virtual cities and landscapes which are amongst the earliest and most traditional of such environments, and then questions of the human-computer interaction (HCI) which involve interfaces and user immersion. We then illustrate developments in virtual realities, virtual worlds, and games, progressing through the currently most dramatic of ways of relating users and GIS through Web 2.0 technologies and services which are rapidly dominating the way all of us are engaging with contemporary computers, computation, and communications. We will interweave this discussion with comments about the media used to communicate and interact with such realities which define the hardware, software and data that compose our characterizations of VGEs.

Virtual Cities and Virtual Landscapes

The traditional expression of reality in GIS has always been in terms of the representation of landscapes. GIS really emerged from a concern for representing and simulating landscapes and the many factors that determine their form—topography, vegetation, climate, human settlement, underlying geology, agriculture and so on. In fact the idea of (data) layers which dominated GIS came from landscape. From the earliest times in the Harvard Computer

Graphics Laboratory which spawned much of the software and expertise in use today, there was a concern with moving digital representation beyond 2D into 3D, imparting even more realism into the way such geographic information might be viewed and displayed[4].

Much of this early work involved vector graphics displays which did not store the picture or imagery in computer memory but simply traced out the image on the oscilloscope, drawing the media in a painfully slow manner with refresh constituting a redrawing of the same image. It was not until the advent of the PC that computer memory became cheap enough to enable pictures to be stored in memory, and thence peeked and poked to enable changes to be made directly on the display device. In fact, computer graphics and the entire graphical user interface is a product of the PC age with the earliest Apple machines leading the way in visual computing, games and in the earliest applications of CAD. Minicomputers too were fashioned to store pictures in memory and some of the earliest fly throughs of cities were produced by powerful (but largely non-interactive from the user's point of view) computers that produced pictures and wire frames[5]. In fact, computers which are now essentially desktop devices for accessing remote resources over networks which are stored on servers are largely visual devices for accessing information which is generally displayed in pictorial terms. *Virtual landscapes* were the forerunner of such displays in GIS with *virtual cities* being the product very largely of the computer-aided design (CAD) industry. Needless to say these two kinds of 3D environment are beginning to merge with GIS extending into 3D and bringing with it its concern for spatial data structures, query and search, and CAD moving back to GIS bringing with it is its focus on rendering and realism. There is enormous convergence taking place in these fields, particularly with respect to software and these are beginning to embrace other technologies such as those that feature in photogrammetry, image processing and remote sensing.

Although virtual cities were the forerunners of VGEs and many VGEs continue to embrace their form, the predominant form of interaction is with the single user sitting at the desktop operating a software system that enables the users to interact with data in the environment, through actual manipulation of the data and/or through query and search. Extensions to multi-user versions are still quite rare for the scale and size of such systems still means that for many to interact, offline versions of the media need to be produced. Movies thus figure significantly in being able to distribute such media to audiences larger than those that can sit in the theater or around the desktop to view and interact with the environment. In this book, the contributions that deal with virtual cities and landscapes tend to assume that many users will use these systems but the focus is more generally on how such environments are to be made as realistic as possible using automated techniques as well as how users can best interact with such media in terms of the interactions that are possible, either through the Web or on the desktop. This brings us quite naturally to HCI and user interaction which increasingly marks out VGEs for other forms of virtual reality.

User Interfaces and Immersion

Our working definition of a VGE is of an environment which is explicitly geographical but into which users are more deeply embedded in terms of the experiences they require than those which have hitherto characterized the uses of GIS. In this sense, the purposes of these environments need to be closely defined for these are not quite the same as those which define virtual cities or landscapes although they are quite close. The classic functions of GIS involve data representation and manipulation of different representations for purposes of analysis—for determining patterns in data and for making sense of these patterns. The role of query and search within such spatial data also provides a key set of functions but these tend to be for a more exploratory role than the earliest forms of spatial analysis which are deeply embodied within GIS. In fact this distinction between search or exploration, and analysis is one that has evolved GIS into two significantly different roles—the traditional one of somewhat passive spatial analysis relevant to strategic issues, and a more recent, more active one of the use of GIS for routine analysis and exploration, for query and search by users who simply require structured information for routine tasks. The line between the two of course is increasingly blurred but it is significant.

In interacting in these ways with geographic information, the degree of realism of such data, particularly for users who require routine information, is important. Moreover the way this realism is imparted to users is crucial if the information is to be useful and relevant for the purposes in hand and this involves the design of good interfaces. The field of cartography has had a long tradition in developing 2D maps that are useful and relevant to users under different conditions and there is a wealth of detail about how to design good maps. Much of this is being brought to bear on the design of VGEs. Several contributions here deal with how such knowledge can be exploited and progressed to enable users to interact better with both 2D and 3D environments which are fixed or mobile. In fact some of the greatest challenges are in the design of interfaces which are limited by the size of the display and the frequency of updating which, in turn, are best reflected in the design requirements of VGEs on mobile devices. As readers will see, mobility and dynamics tend to be key issues in the development and use of VGEs not only for user interfaces but also for the way information is acquired, displayed, refreshed, and animated.

Search at the local level is becoming extremely significant at the present time as mobile devices with GPS merge with phones and the Web. For example, the digital earth paradigm that crops up at several points in various contributions published here is driving forward the search for local content which might be user generated as well as synthesized from a variety of public and private sector sources. This is taxing our best interface designers who are required push as much as possible about the real onto the virtual screen of small display devices and to organize this data and its graphics in such a way that confusion is minimized. The same kind of problem exists at the other end of the spectrum where users of VGEs are involved in much more generic issues of public participation. These tend to be systems where immediate feedback and response is not required and thus the dictates of spontaneous and instant search are not needed. But the same kinds of problem about vast quantities of seemingly relevant data that need to be synthesized easily and cogently apply. To an extent, the media is independent of this kind of user interaction for routine information of a specific or general nature might be accessed on any of the device that can connect us to such data sources from the small scale mobile to the VR theater. But the media does structure what is possible in terms of interfaces and the challenge is to design interaction systems that are flexible and adaptable for different problems, devices, and patterns of digital connectivity.

The last problem we want to signal here is perhaps the least tractable and that is "how can traditional systems of GIS which build on GI Science and spatial analysis be made more virtual so that users can explore and analysis patterns in geographic data more effectively?" GIS has moved slowly from systems that are all embracing to tool boxes that involve users in plugging and playing all the way to modules that can be fashioned into rather different systems that interact with quite diverse software. Extensions that plug into agent-based modeling packages and into CAD, for example, are now available[6]. There is a drift towards the Web with non-proprietary tool boxes of GIS-like functions being quite widely available. But so far, there has been little attention to good interface design, apart from moves within the information visualization community which link closely to exploratory spatial data analysis. In fact one of the conclusions from this survey of VGEs is that much more attention should be given to traditional GIS and its interfaces so that users can fashion data for themselves in innovative ways that give them control over the interface. Just as more general and widely available software can be customized to the requirements of different users, we believe that the same kind of developments should occur in GIS. In this, VGEs can point the way.

Games and Virtual Worlds

One of the more surprising developments in GIS (and CAD) is coming from digital entertainment, from games and their online equivalents ranging from systems such as World of Warcraft to virtual worlds such as Second Life. Gaming brings with it the need for realism which can be part fictional as well as real in the real world sense. Realism, however, at the most detailed level poses enormous challenges for standards to which graphics and all other user senses must accord. Game players demand realism of a kind that is as good as it can get whereas those dealing with virtual cities built in CAD and GIS tend to accept a level of abstraction that implies a good deal less realism than would be acceptable for gamers. In fact, we do not have much idea of what level of realism is required for routine search on mobile devices or in terms of the interaction of the public with digital planning schemes and models. To an extent, the standards that prevail on the web and in graphical user interfaces generally are those that tend to be accepted by default. We still do not know how much better our VGEs would be were we to develop the sort of standards that occur in gaming.

In virtual worlds too, although the realism is good, given the kinds of objects that inhabit such worlds—people as avatars, buildings, landscapes, and so on, the general impression is one of a cartoon-like quality that tends to divert the serious user. As several of these contributions here suggest, games and virtual worlds provide enormous potential for VGEs but their interfaces tend to look amateurish and rather clunky. Given the memory requirements that need to be met and the need to scale such systems to millions of users, the overall, effects of such worlds are good although it will take a while before the needed realism can be reached. However this is only matter of time as servers and clients improve in their memories and as access via broadband communication continues to improve. Nevertheless, these kinds of games and worlds do show what is possible as they are instructive in pressing home the message that in the future, all such virtual realities will be online.

The requirement for online access has remained implicit in our discussions so far although we might be reaching the point where VGEs are explicitly networked constructions and where users engage with each other and with the environment in a mixture of local and online actions and interactions. In fact, of the twenty one contributions to this book that follow, there are only four that do not deal with online and remote access as integral to the environments that are discussed and even these are developed against a background of networked data and information that is essential to their construction. One of the problems of course in gaming and virtual worlds is that there are so many human and physical processes required that the graphics is bound to look artificial as designers trade off realism for efficiency of execution. These environments require iconic and symbolic models—based on geometric representation and simulation as well as mathematical and logical representations of the processes involved. These are important issues as it is here that we see the true merger of the geographic, the geometric, and the processes and behaviors that characterize the real world. For example, the sort of models developed for pedestrian motion as well as those for geometric integrity of virtual cities are merged in virtual worlds. Combine these with the needs of real users entering these worlds and partaking in debate and discussion where virtual geometries and background human and physical processes form part of the constantly updatable backcloth on which this action takes place, then this gives some idea of the challenges involved in this quest. As various contributors argue here, games and virtual worlds tax our abilities to abstract and represent while at the same time challenging us to make our interfaces better.

Web 2.0 Technologies, Digital Earth, and Neogeography

Our last topic area that weaves itself throughout all the contributions here is the first we broach in Part One of this book. This is the online world, the world of networks, communications, and dissemination and of course, of users. It is the world where users meet software whether it be simply before the desktop or workstation or more likely through some mix of the real and the virtual, the immediate and the remote. The Web which began in the early

1990s nearly two decades ago, was quickly fashioned through graphical user interfaces which are still called browsers and through which increasingly remote and standalone software is now being delivered and accessed. Most of the access to data and software through the web is relatively passive in form but we have moved into a phase of interactivity that lets users change the content of the information they are using on the fly, so to speak. They are able to add new content from diverse sources, improve the content if they see fit, or even abuse it, subject to the "wisdom of crowds" which acts a restraining force on what is produced and made available publicly. These systems, accessible through the Web still in the form of Web pages, are often referred to as web-based services although a more accurate depiction would be as fully interactive systems, in fact virtual environments, in which users can interact as though they are in the real world by making changes, additions or deletions as well as simply passively observing the information in question. Everything from Facebook to Wikipedia are part of such services. The key is to let users manipulate the content and this is the criterion that distinguishes the original Web, Web 1.0 from its contemporary equivalent, Web 2.0.

Geographical services such as Google Maps and the range of digital earths from Google and Microsoft amongst others that have recently appeared are not strictly Web 2.0 services. However, once introduced, these companies have enabled these frameworks so that users can customize them. In terms of Google Earth, the Google 3D Warehouse lets users upload their buildings and make them available for others to download. Google MyMaps lets users customize their maps and embed them in other services while also linking these to local search which in fact is one of the most important commercial rationales for such developments. Copyright and IPR issues of course pervade these kinds of open access but the open source movement and the notion that in the digital world, the marginal cost of information is near zero, has begun to dominate. Companies and agencies can thus afford to give 99 percent of these services away for free and simply make their money on the remaining 1 percent which they can customize for niche markets. The business model for such developments has a logic of necessity where it is easy and almost costless to distribute content, one which is highly empathetic to users who create their own content as well.

The world of crowd sourced information which is upon us is leading to the creation of geographic data and content from the most unlikely sources. Combined with GPS, an army of volunteers are creating products such as OpenStreetMap, a user sourced digital map (of the world) that can be added to at will and improved in much the same way that Wikipedia has become the world's most advanced and informative encyclopedia. This, combined with the ability to take various map products such as Google Maps and customize them into open GISs, is leading to the creation of a new kind of bottom up geography—*neogeography* as it has been labeled[7]—which opens mapping to the masses. VGEs to date have been more professional in scope but scattered throughout this book are examples where such systems are opening up to non-expert and non-professional users who are likely to change and improve the contents of these virtual environments in ways that are beyond our wildest dreams.

Therein likes the power of the Web; the rise of neogeography threatens to change the nature of the way we handle and abstract geographic space for ever.

The Prospects for Virtual Geographic Environments: The Contributions That Follow

We do not intend to write a conclusion to all the contributions in this book that follow. We feel they speak for themselves as a snapshot of where we stand in GIS and GI Science with respect to our needs and expertise in embracing the virtual world and using it creatively to advance our use and applications of geography. One of the features that will strike the reader who ventures beyond our initial foray in what VGEs are all about is that the organization of the five parts that comprise this book are somewhat fluid. Virtuality runs throughout the parts as does GIS for most of the participants emanate from the community of GIS scholars. But ideas about mobility and dynamics merge with ideas about the power of the web and the rise of neogeography. In some senses, we speculate that VGEs will be very different constructions a decade or more in the future for the whole question of realism will be handled much more cleverly and professionally. User interfaces will be better but there may well be as many gimmicks. The graphic effects in movies like “The Matrix” and “Minority Report”, the “1984s” of the Twenty First Century, could well come to pass as mobile devices get wired into ourselves and as a plethora of information continues to bombard our senses. With all this, we may well see a return to or rather a clearer distinction between professional uses of GIS in terms of the software for spatial analysis and its more routine use as web-based services. This then is for the future. In the meantime, the contributions which follow provide some sense of the state of the art.

First off, we review the overall power of the Web with respect to the fashioning of virtual geographic environments. Goodchild, Hudson-Smith and Crooks sketch the growing impact of Web 2.0 with respect to map hacks, volunteered geographic information, and customized non-proprietary applications. Many of these are likely to change the face of conventional GIS as Peuquet suggests in her review of integrated space-time systems which are geared to good user interaction. Tao turns the argument around in his review of the need for local search which he then suggests is driving the evolution of new forms of geographic information systems which build on the concepts of the digital earth.

The second part returns to more conventional applications in the form of virtual cities and virtual landscapes. Yano and his colleagues show how their Virtual Kyoto models link space to time as users navigate the environment to gain some sense of this Japanese heritage. At the same time they show how buildings need to be generated routinely and automatically to build such environments. This is echoed in Middel and her colleagues Digital Phoenix project where the output is more abstract but converted into realistic pictures for participation using similar rendering and generative schemes. This theme is extended by Lovett and his colleagues who, looking at virtual landscapes, explore the realism imparted by their realization on different systems while Sugihara and Hayashi illustrate how really quite sophisticated generative schemes are necessary to get the detail of the virtual city to the point where it is acceptable for viewing by a wider public.

Many of these issues involve appropriate user interfaces for experts and the public in using VGEs and in the third part of the book, this becomes the focus. Meng presents some important concepts which enable users to interact with geographic objects effectively illustrating various examples from digital cartography. Cai does the same but in the quest to generate the wider context of a VGE which is web enabled while at the same time being implementable on mobile devices. Jahnke and his group return to the idea of generating vast arrays of content for virtual cities using non-photorealistic data which must be tuned for various kinds of user. The tone then switches to public participation with an integrated system for urban design and townscape analysis being illustrated by Shen and his team. Portugali's group then sketch how VR, CAD and GIS can be nested in a decision support system which enables commentary on the barrier being created between two very different communities in Israel and Palestine.

The fourth and fifth parts of the book tend to be a little more technical dealing with mobility and dynamics in VGEs in networked and mobile contexts from large to small scale. Li and his group first show how uncertainty in positioning needs to be transmitted to users of VR system while Yanagisawa and Yoshikawa quantify information being delivered to mobile hand held devices so that the information can be optimized in terms of its delivery and form. The debate then moves to slightly larger scales. Deren Li shows how his group are constructing VGEs from digital measurable images that form the essence of a digital earth, and then Jianhua and his colleagues present the network dynamics involved in building a VGE. This focus on mobility is continued in the fifth part, where the emphasis turns to small scale movements. Arikawa and his group show how small scale environments involved with movement need to be developed with specific natural language processing to yield good data on movement while Wu and his colleagues illustrate how to build a pedestrian model for entertainment events in down-town Hong Kong. Gong and Mackett focus on measuring actual walking behavior and linking this to visualization techniques. Finally, the Shepherds, somewhat rhetorically, pose the question "Can videogame technology replace GIS?" by which they mean that the motion technologies and dynamic modeling in such games might provide a paradigm both for GIS as it extends into the temporal domain and quite clearly for VGEs.

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