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**Virtual Cities: Digital Mirrors
into a Recursive World**

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Virtual Cities: Digital Mirrors into a Recursive World

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Abstract

Digital cities are moving well beyond their original conceptions as entities representing the way computers and communications are hard wired into the fabric of the city itself or as being embodied in software so the real city might be manipulated *in silico* for professional purposes. As cities have become more ‘computable’, capable of manipulation through their digital content, large areas of social life are migrating to the web, becoming online so-to-speak. Here we focus on the virtual city in software, presenting our speculations about how such cities are moving beyond the desktop to the point where they are rapidly becoming the desktop itself. But a desktop with a difference, a desktop that is part of the web, characterized by a new generation of interactivity between users located at any time in any place. We first outline the state of the art in virtual city building drawing on the concept of mirror worlds and then comment on the emergence of Web 2.0 and the interactivity that it presumes. We characterize these developments in terms of virtual cities through the virtual world of *Second Life*, showing how such worlds are moving to the point where serious scientific content and dialogue is characterizing their use often through the metaphor of the city itself.

Introduction

The idea of the ‘computable city’ is one that stretches back to a time when the convergence of computers and communications first began to make an impact on the way cities functioned. New forms of electronic interaction began to display themselves in the need for wired infrastructures to support everything from smart buildings to new kinds of

information industry (Batty, 1997). The notion that the city through its hardware might become 'intelligent' is something that has been with us since the 1980s. But during this time a somewhat different prospect has emerged with the city itself and its many functions being encapsulated and articulated in non-physical terms, in virtual space rather than real space. At first the impact of the internet was largely in terms of cities advertising their services to 'virtual tourists' who browsed or shopped the web through simple passive browsing. The early web site *Virtual Bologna* represented the portal to urban services and information about the Italian town of Bologna which became a favourite example of early commentators on the power of the web.

Virtual Bologna was typical of its time with its iconic representation of the city as a gateway to real urban information but what is now happening is that these many technologies which display and transmit information in somewhat passive terms through the web are beginning to take on new forms of interactivity. Increasingly cities and city-like media are being captured on the web and disseminated not as passive web pages but through virtual worlds where the user enters a digital space that is in many ways akin to a real space and engages in interactions which mirror what happens in real space. Virtual cities are being built and inhabited using systems such as *Second Life*, with millions of users making rapid decisions thus shifting these virtual realities minute by minute into new manifestations of digital urban form.

The concept of the 'computable city' is still alive and well in the city itself as more and more computable devices exist within our physical environment. We have not quite reached the stage where such devices are embedded into themselves but all this is becoming routine. It is in terms of what is happening within the computer itself that now marks the cutting edge. The circle has turned completely: computers in cities exist in abundance of course, but it is cities inside computers that now define the digital frontier. This notion of the 'city inside the computer' changes rather remarkably our vision of how one can build virtual cities. Rather than being based on any single real place, they increasingly embody a mix of fiction and reality, digital cities linked together in a virtual urban sprawl, forming part of the 'metaverse' so eloquently anticipated by Stephenson and Gibson, that genre of science fiction writers that based their visions of the near future on ways in which the physical and virtual merge.

Virtual Space

There is a never ending debate about whether or not our knowledge of space is hard wired into each of us or whether it is acquired from early childhood through our senses. However insubstantial and invisible space might appear from an analytic perspective, space is somehow everywhere around us. For most of us, space most hovers between ordinary, physical existence and something that is imposed on us. It alternates in our minds between the analysable and the absolutely given (Benedikt, 1996). In terms of our interpretation of it and the resulting all-important sense of location and place that it inspires, it has a profound influence on our perceptions of reality and of course on the digital worlds that we might create based on such perceptions. Indeed space strongly conditions the way we represent a variety of phenomena, the way we present information,

the way we act, and behave in general and it is clear that when we fashion information in the digital world, the metaphor of real space powerfully conditions what we do. Yet it is also clear that because of the digital world, our conception of space is changing. The digital world that beckons, forces us to revise our view of the absolute nature of space. In the virtual world, the constraints of real space, of machine space, and the idea of iconic cities, can be massively relaxed. Virtual space can be nested into itself as many times as one likes, in recursive fashion as we gain the power to embed any digital representation into any other but more specifically into the very digital object that forms the focus in the first place. In this sense, the digital world acts as a mirror, enabling us to scale and transform any object into any other but through processes of embedding an object into itself. It is this that profoundly changes the way we are able to interact with each other in virtual space (Batty and Hudson-Smith, 2007).

Virtual cities began as digital representations of real cities essentially mirroring their physical form in the most superficial way. They were initially designed so that professionals such as architects and engineers might create environments that could be rapidly and effectively communicated to others for purposes of architectural design urban planning, and a host of serious tasks that defined what cities are about and how they might function better. Traditional digital cities are focused on how to create, represent and communicate place and space on some computerised device, originally made available on some graphics output linked to a digital computer. The type of device has always been central to the nature of such simulations. Once three dimensional representations were limited to high-end mainframe machines but now they have proliferated to the domain of the standard desktop/laptop, the portable hand-held device, GPS-enabled mobile phones and in-car satellite navigation consoles. Doubtless digital cities of this kind which represent icons of the real city can be displayed on any digital device one might imagine. In these terms they have barely moved beyond an obvious representation of the real thing but in digital space. It is an open question as to whether or not these types of cities might be called virtual. In this chapter, we will show how true virtual cities are moving well beyond these initial conceptions.

Machine Space

There are two central ideas in developing virtual cities into forms where they can be endlessly manipulated in digital terms. First is the idea of the 'Mirror World' first promoted by David Gelernter (1991) in his seminal book *Mirror Worlds: or the Day Software Puts the Universe in a Shoebox*. Gelernter (1991) defines 'mirror worlds' as software models of some chunk of reality, some piece of the real world going on 'outside your window' which can be represented digitally and then rescaled again and again into a form which you can enter and manipulate. However a mirror world is grounded in some real space and its power comes from the way we manipulate the reality. Gelernter (1991) predicted that a 'software model of your city, once set up, will be available (like a public park) to however many people are interested ... it will sustain a million different views ... each visitor will zoom in and pan around and roam through the model as he chooses' (Roush, 2007). In short, mirror worlds are a version of reality existing in the machine, a

‘machine space’ which in turn can be defined as the ‘ParaVerse’, or ‘... a parallel virtual world geographically linked to the planet earth or other bodies in the physical universe...’ (http://en.wikipedia.org/wiki/Virtual_world). Our view of mirror worlds in city terms is many-fold but all relate back to the physical reality of the real city: as a city that represents the real world inside the computer, as computable space, or as a ‘city in the computer’.

Virtual worlds, as distinct from mirror worlds, are worlds which may resemble in many sense the real world but which in essence are worlds created without importing any iconic representation which is tuned to match a real world. This the definition given by the authors of the *Metaverse Roadmap* (Smart, Cascio, and Paffendorf, 2007) who make the distinction between mirror and virtual worlds as one which relates to the source of the media. However as they imply, virtual worlds are unlikely to exist in pure form and increasingly worlds such as *Second Life* are full of material that represents digital icons from the real world; indeed as we will show, it is possible to embed digital representations of the real world – digital cities as mirror worlds – into virtual worlds, thus changing their definition and vastly muddying the digital waters through this kind of intersection. In short virtual worlds are now emerging that we might refer to as virtual mirror worlds which contain both real and fictional media. It is this ability to blend both that marks the way in which virtual worlds are now being used.

To take this argument much further, we must define what we mean by space in a little more detail. Bell (1996) identifies three different kinds of space: visual, informational and perceptual. Visual space is real three dimensional space around us and is defined in terms of all that a normal person can see. It is the array of objects that surrounds us, which we can create collectively, and which we take to be our environment. Each of the objects that comprises this environment has a multitude of different physical attributes, from variations in light and colour to reflectivity. These objects create reality, a fully immersive environment in Cartesian space that can be interrupted and explored by us directly in its three dimensions. In formal geometric terms, if these objects are broken down to singular levels, then each object can be viewed as being made up of a combination of primitives. Primitives are a collection of graphic tokens such as points, lines, and polygons, forming a two-dimensional or three-dimensional arrangement, and it is convenient to think of visual space as being populated by these tokens (Mitchell, 1994). If these points, lines and polygons can be recreated in digital space along with their attributes, then digital space becomes iconic, mimicking and simulating the physical reality, thus creating a mirror of the real world, a ‘mirror world’ existing in a digital space.

Informational space can be defined as an overlay to visual space as the space in which we communicate and receive information, from urban signage to oral communication. In the digital realm, information is rarely set up in a separate space but becomes an additional attribute of any digital icon defined with reference to its physical space. Digital information takes the form of an embedding of data within digital space or the enabling of communication within a digitally generated environment. Information can illuminate, transform, or displace reality (Borgmann, 1999). With the addition of communication to

convey informational space, overlaps occur between the third form of space, that of social or perceptual space. Social space defines the user's identity and role in relation to other users in the visual environment. In digital space, the user's identity is again an additional attribute, explored later in terms of its embodiment and presence in virtual environments. Thus the combination of visual, informational, and social space influences the individual's perception of reality, be it in the real or digital environment, and this is what we define as perceptual space which is key to the digital representation of the built environment. Using digital technologies, reality cannot only be modelled and displayed on the computer screen in the form of points, lines and polygons, but it can also be augmented, manipulated, violated and transformed into environments that convolute the original representations into the wildest of fantasies.

Benedikt (1996) argues that because virtual worlds are not real in the material sense, many of the axioms of topology and geometry so compellingly observed to be an integral part of nature can therefore be violated or reinvented as can many of the laws of physics. It is this reinvention that allows attributes to be enhanced and emphasized, and the laws of gravity, density and weight to be excluded, allowing buildings to be moved with the click of a mouse or allowing the user to fly above the environment. Reality can thus be made virtual and at the same time the virtual can be recursed back and forth into and out of the reality, augmenting it, changing it. But before we explore such concepts, it is useful to take a brief look at how we create this digital space.

Virtual Cities as New Digital Spaces

The first step on the road to creating a virtual city, a city where bricks and mortar, buildings and their materials are represented as polygons and textures, is digital data. Data is key to our knowledge and understanding of the form of the city but its geometry must be distinguished from its other more substantive attributes which might be both physical and social. The geometry is the raw material comprising the skeleton of streets and buildings, natural vegetation, terrain and so on that provides the physical form used to tag other physical and social attributes. The geometry thus represents the geo-coordinates of the system to which other data can be tagged. Such data is often represented as layers to differentiate and classify different types and in principle, an infinite number of layers can be placed into the cityscape representing the real and/or fictional icons of the world in question. Data thus drives the formation of virtual cities in their mirror worlds and it is the wide array of possible data types that have become available for real cities that is aiding new visualisations and understandings in virtual space.

Our current model which provides a geometric data base for tagging extensive attribute data about Greater London, evolved from a simple model of central London using in the first instance 3D-GIS (geographic information systems) technologies. *Virtual London*, as it is currently called, was then extended to some 3.6 million building blocks covering the 33 boroughs comprising Greater London, an areal extent of some 1600 square kilometres. (Batty and Hudson-Smith, 2005). The model has been tagged with air pollution data, land

use, retail data in surface form, it has been flooded as part of our quest to understand issues of climate change, and it has been used for various kinds of simple viewshed analysis involving the impact of high buildings. It is currently developed in *ArcScene* (which is part of *ArcGIS*) but freely ported to other CAD packages, particularly *3D Studio Max* from which movies are made and into which other media such as panoramas, still photographs and fixed animations can be embedded. We show some images from the current model in Figure 1.

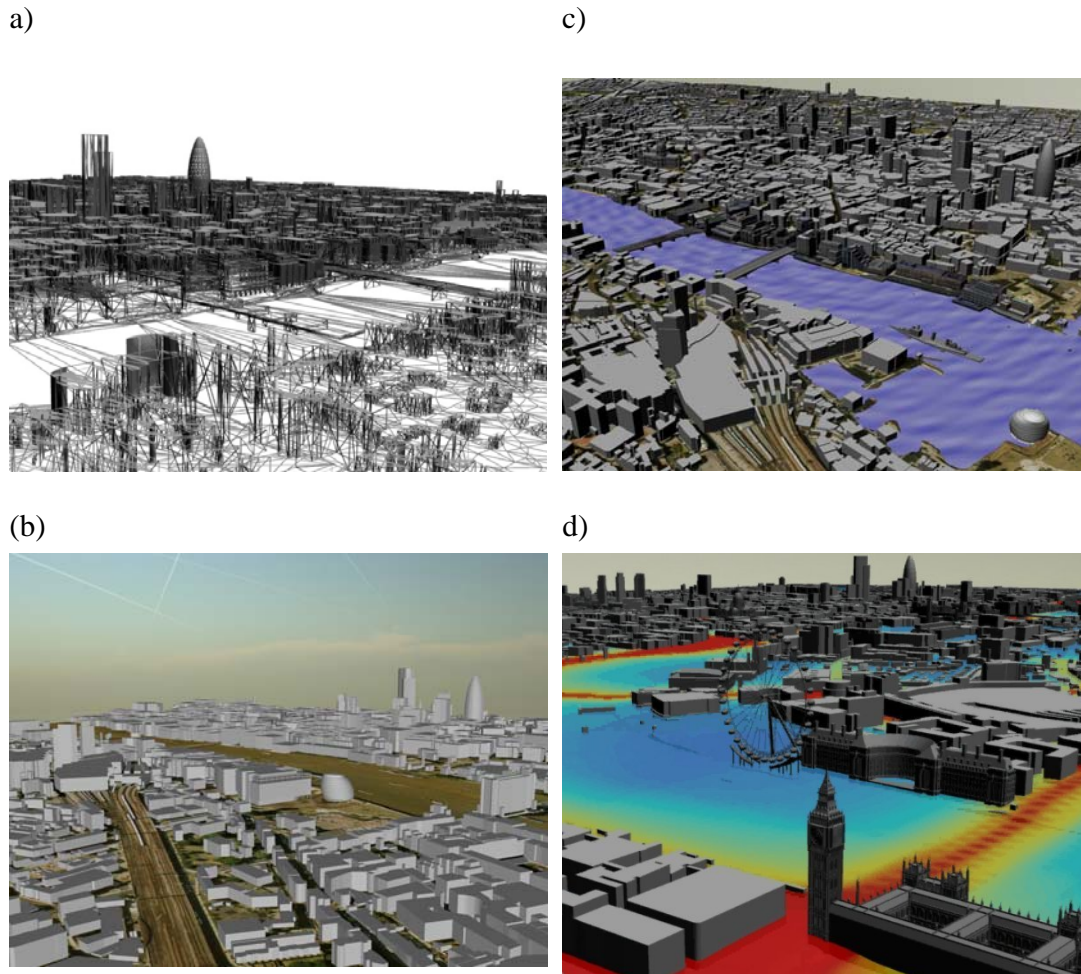


Figure 1: Virtual London as a Mirror World

- a) The Geometric Skeleton
- b) the Digital Block Model,
- c) Flooding the Model with a 3 Metre Rise in the River Thames, and
- d) Layering an Air Pollution Map (NO_x) on the Model

Building *Virtual London* in a virtual world however relaxes the constraints we have adopted on developing the model quite considerably. The way virtual worlds operate with free entry of visitors as well as a considerable cadre of members who have rights over what and where to build, makes a focussed virtual city of the kind that comprises *Virtual London* almost impossible to create. Apart from the fact that construction is slow,

individualistic and somewhat uncoordinated in comparison to the geometric strictures necessary for digital construction in professional VR, CAD and GIS software systems, the notion of letting the geometry flow differently in such worlds is a central feature. We have experimented with such worlds quite widely beginning with early versions such as *Blaxxun* and *Active Worlds* where the focus was not on real data *per se* (see Hudson-Smith, 2002), moving to more structured forms in *Adobe Atmosphere* where we built virtual exhibition spaces to house our iconic simulations, importing whole city blocks from *Virtual London*. Even so, our ability to produce realistic renderings and data layers as we do in *Virtual London* and employ the media for the same professional uses in property analysis, urban design and transport planning, is limited. Some of these early experiments are shown in Figure 2.

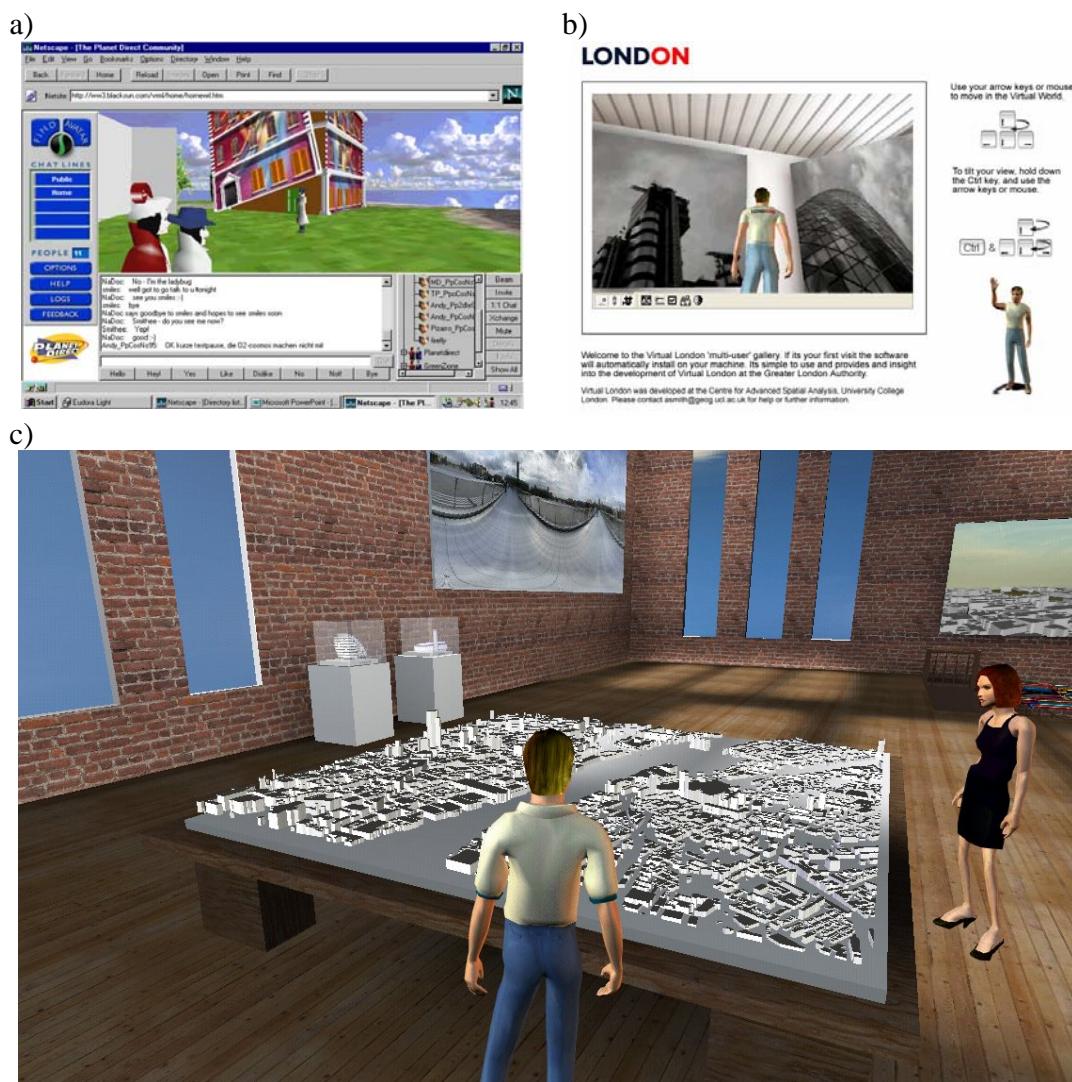


Figure 2: The Evolution of Virtual Worlds

a) An Early Rendition of Building in **Blaxxun** b) A Virtual Gallery c) Virtual London in **Adobe Atmosphere**

However the current generation of virtual worlds software enables users to generate much greater realism and many more users to experience this content. The key difference between mirror worlds and virtual worlds is the way interaction with users is enabled. Mirror worlds as *Virtual London* are usually constructed for single user use, for professional use where at most a set of users coordinates their use of the model. It is rare to find several users using the same model as a tool in which to structure their negotiations over design proposals, for example, although this is possible. Much more likely is the use of the models pictured in Figure 1 as tools to enable one-off rather focussed assessments of the future form of cities rather than as playgrounds for widespread experimentation. Moreover virtual worlds engage the community of users through the web which opens their use to whoever is connected (within the obvious limits of membership and censorship). This ability of many to engage and interact is the key feature that defines Web 2.0 where interaction is the key and where most access is currently achieved through graphical user interfaces. Virtual worlds take this visualisation to the point where users can freely experiment in interacting through real or fictional environments. It is quite rare, for example, to see environments which are entirely one or the other. Users do not yet have the power to easily import entire city blocks but more to the point, there is more limited control over content than in the mirror world. Yet what is happening as we alluded to earlier is that virtual worlds are being populated by mirror worlds, implying a recursion of digital content that is clear from the early examples and is progressing rapidly in newer worlds such as *Second Life*. In Figure 3, we show Digital Amsterdam (or some blocks representing that city) as they have been rendered in *Second Life*. Such applications clearly point up the message that these worlds can potentially engage users in many different pursuits, not only in leisure but also in serious science. Who knows? This may be the way of much science in the medium term future, and it is certainly the challenge of Web 2.0.



*Figure 3: Virtual Amsterdam, a Mirror World Displayed in the Virtual World of **Second Life***

Web 2.0 and Neogeography

It is now quite clear that the connectivity produced through the internet enables us to interact across time and space in ways that our ancestors could only dream about. This is based largely on the convergence of computers and communications that two or more generations ago were largely unforeseen even by those who were working with network interfaces to computers themselves. Once these networks were put in place by the late 1990s, then the prospect of using them to compute gradually began to dawn. Sun's old adage and advertising slogan (circa 1992) "The network is the computer" promised a taste of things to come. Now much if not most digital media is being communicated across the internet.

Only quite recently and certainly since the Millennium has the prospect of using the interactivity of the net become significant, and only now does it appear that in the future this will be the net's main focus. In short, the notion of people communicating and manipulating digital content together and in concert or using it against one another for less benign reasons is the prospect that awaits us. As this kind of interactivity which is sometimes called social networking, gathers pace, then for those of us immersed in notions about building and using the digital city, the prospect of a global community of users who would exploit, extend and develop this digital metaphor in ways we have never anticipated, is gaining pace.

The key to all this is location, geography. We will argue here that location and space this now represents a third force in information technology besides computers and communications. Tagging not only the type of information but where such information is produced, who uses it and at what time it is generated is fast becoming the killer application that roots information about interactivity generated across the web to systems that users can easily access and use in their own interactions with others. GPS (Geo-Positioning Satellite) technologies are at the forefront of this revolution but it is their universal dissemination – first through in-car devices – and now just about through mobile phones – while in the future being embedded in multiple objects that can be carried on the person or in a transport, that is driving this revolution in tagging. Already much is being accomplished and mapping systems such as *Google Maps* are simply the vanguard of a whole series of software systems and virtual worlds that promise to bring geo-location to the fore, and of course to everyone.

This re-emergence of the importance of geography in the Web 2.0 world is becoming known as 'Neogeography'. This is the geography of the everyday person using Web 2.0 techniques to create and overlay their own locational and related information on and into systems that mirror the real world. The term derives from Eisnor (2006) one of the founders of www.platial.com where she defines it (Neogeography) as: "...a diverse set of practices that operate outside, or alongside, or in the manner of, the practices of professional geographers. Rather than making claims on scientific standards, methodologies of Neogeography tend towards the intuitive, expressive, personal, absurd, and/or artistic, but may just be idiosyncratic applications of 'real' geographic techniques. This is not to say that these practices are of no use to the cartographic/geographic

sciences, but that they just usually don't conform to the protocols of professional practice". Turner (2006) expands the definition considerably in his pamphlet on the various techniques which non-professional users now have at their disposal. He says: "... a Neogeographer uses a mapping API like *Google Maps*, talks about GPX versus KML, and geotags his photos to make a map of his summer vacation. Essentially, Neogeography is about people using and creating their own maps, on their own terms and by combining elements of an existing toolset".

The city has thus become a focal point for such visualisations where locational information is added either collectively but mostly individually to some web site or web application that enables the user to tag him or herself in space and time. As the majority of users of these systems currently live in cities or at least urban areas, it is not surprising that the city is one of the key metaphors for Web 2.0. The ways locational information is added to these applications where a website or application combines content from more than one source into an integrated experience, is known collectively as a 'mashup'. In many ways, Neogeography and mashups go hand in hand. Our *Virtual London* model is mashup as the illustrations in Figures 1 and 2 imply. Kopomaa (2000) states that the wonder which virtual spaces awaken in people wandering in the electronic labyrinths of information networks, may also be exploited to revitalize our physical cities if cities are placed in such worlds which exploit the sensitivities and sensibilities of their members and visitors. Indeed a primary aim of our model has always been to inform the public and professionals alike about the future of the city. One of the prospects of Web 2.0 for virtual cities is that as these cities develop over time, new software, new data sources and new ways of digital building will become available. The fluidity that Web 2.0 enables with its focus on individualised updating of information in the locational sense augurs well for highly responsive and timely interventions in real cities. Indeed it is the fluidity of the city that is key to Neogeography as a whole.

Without question the most important innovation in the development of the digital city, its Neogeography, and the mashups that accompany this, is the concept of the digital earth. *Google Earth* and to an increasing extent Microsoft's *Virtual Earth* and NASA's *World Wind* have produced digital cities at a speed and resolution that was unimaginable only a few years ago. These cities act as the base layers for information, a rich canvas onto and into which information can be inserted and extracted at will over the network. In essence they act as our 'space in the machine', a space which can be iconic, photorealistic or multifaceted depending on the user's preference. It is into this space that spatial analysis systems such as space syntax operate, software for analyzing space. Indeed Hillier (1992) actually defines 'space as the machine' and this mirrors a traditional professional usage which is a starting point. But once we grasp the notion that we can put space into the machine, we can then put the machine into the space, digitally, in recursive fashion where the machine *is* space, the space.

In this chapter, we will now explore the way neogeographic systems are being developed to influence both the development of mirror and virtual worlds. *Google Earth* is the example *par excellence* which was born out of Keyhole, a company founded by John Hawke with the aim of creating a 3D program called *Earth* (Roush, 2007). Of note is

Hawke’s inspiration from Neal Stephenson’s (1992) science fiction novel *Snow Crash* which describes a virtual earth created by the Central Intelligence Corporation (CIC). In this context, it is worth quoting Stephenson: “There is something new: A globe about the size of a grapefruit, a perfectly detailed rendition of Planet Earth, hanging in space at arm’s length in front of his eyes. Hiro has heard about this but never seen it. It is a piece of CIC software called, simply, Earth. It is the user interface that CIC uses to keep track of every bit of spatial information that it owns - all the maps, weather data, architectural plans, and satellite surveillance stuff. Hiro has been thinking that in a few years, if he does really well in the intel biz, maybe he will make enough money to subscribe to Earth and get this thing in his office. Now it is suddenly here, free of charge”.

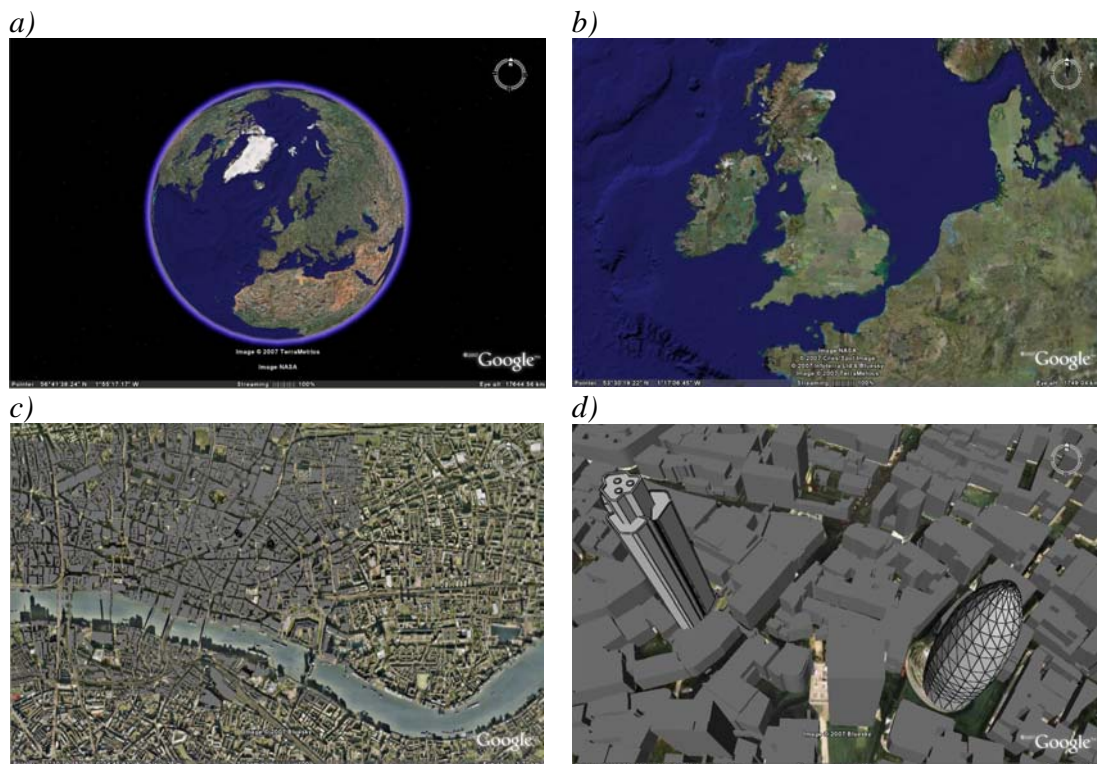


Figure 4: A Framework for Neogeography: *Google Earth* and *Virtual London*

Indeed the rudiments are now free of charge and *Google Earth* is being used already to store all the information that Hiro describes in this piece. We have ported our own *Virtual London* to *Google Earth* for it provides a ‘free’ software platform for many professional users who do not have the commercial software to run and explore our product (see www.digitalurban.blogspot.com). This is not yet Web 2.0 but as we will show, it is an essential first step (or rather second step once the mirror world model has been created) in moving in this direction. Figure 4(a) illustrates an opening shot of *Google Earth* and then content can be loaded into the earth which is tagged in such a way that the user can zoom directly (see Figures 4(b) and (c)) to the scale and place where the content is displayed. In Figure 4(d) we see part of central London – the financial quarter – as 3D building blocks.

Google Earth, released in 2005 is important on three levels to visualization and ultimately to simulation. It is simple to use because it is navigable on the x, y and z axis and thus provides a real world geographic area on which to place data. In order to make *Google Earth* represent the Earth, Google have licensed swathes of data from around the world and made it available to view free of charge. This is a notable change, especially in terms of professional spatial and urban analysis, for it provides access to high-resolution aerial imagery that is essentially free and thus challenges the power and authority of many data suppliers who charge for their data unlike Google and many other Web 2.0 companies. The resolution of the system changes according to location of course with 'Googleplex' (the Google Campus complex) currently providing the highest current level at 2.54cm per pixel. In general the highest resolutions of imagery are focused on urban areas and geographic landmarks. *Google Earth* can thus be seen as our first 'universal' glimpse into the mirror, and although it is by no means a Mirror World in and of itself, it does provide a basis on which to build as our example in Figure 4 reveals. Of particular note is the ability to import three-dimensional objects and data with a time dimension into the world, thus transforming the structure into an interface that supports 4D. Three-dimensional cities sit on top of the high resolution aerial imagery, streamed in from numerous sources, either direct from the Google server, the 3D Warehouse which is a repository of user created models, or direct from a user's machine or server (as in Figure 4).

User created content is central to such systems for no software company has either the money or man power to build a complete mirror world. The power of Web 2.0 is that it provides users with the tools and access to create such content and as such, Google released a free version of their *SketchUp* 3D modelling tool in 2006, opening up the ability (and indeed requests from Google) for users to model their own worlds or versions of the real world. This style of modelling extends far beyond the traditional CAD-based view of the world as data can be attached to high-resolution imagery providing the possibility that built environment composed giga-pixel imagery will eventually be produced.

In creating such cities halfway to virtual worlds but very much part of Web 2.0, there are still technological issues involving ground-based capture of imagery and geometry. It is a slow and semi-professional task to photograph the city and turn it into points, lines and the primitives needed for digital geometric content. Microsoft in their *Virtual Earth* have predominately taken the non-Web 2.0 route, by the building cities themselves using aerial based LiDAR (Light Imagery Detection And Ranging) and photogrammetric techniques. These digital cities are amongst the best renditions of cityscapes anywhere and to date, Microsoft have made available 62 cities throughout the US and Europe with a further 500 planned over the next 12 months. Figure 5 illustrates the kind of content with a view of New York in *Virtual Earth* but it is unlikely that this method will prevail for to model the world will require all the world's resources to be mobilised, and that is the power of Web 2.0.

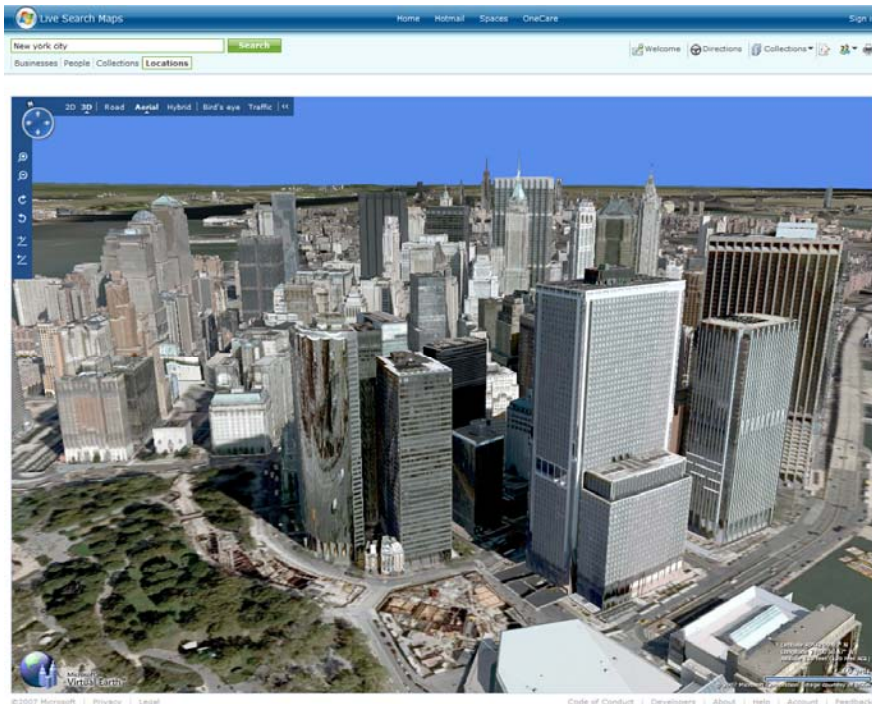


Figure 5: Microsoft's New York in *Virtual Earth*

Towards a Social Space: Building Virtual Cities in Virtual Worlds

Web 2.0 is sometimes defined in terms of social networks and social space. Thus we might add to Bell's (1996) classification of visual, informational and perceptual space by including social space which is an elaboration that broadens the context to include collectivities and groups. Social space is all important. In essence it is the network that binds Web 2.0 and Neogeography to an ability to communicate and share information through simple, freely available tools that can be learnt quickly and effectively without immersion in professional activities. As such, these tools and the way they can be used is redefining the very disciplines that traditionally have made sense of such phenomena – sociology and geography – just as economics is being redefined in Web 2.0 as Wikinomics (Tapscott and Williams, 2006). One such example is *Twitter*, a social network based on text communication which provides both an iconic and recursive view of the city as a whole. Text-based messaging is now part of everyday life. The first text based message was sent in 1992, while SMS (short messaging service) was launched commercially for the first time in 1995 (Wilson, 2005). Text-based messaging is very much part of city life. To give an indication of numbers, 1.2 billion SMS message are sent every week in the UK (2007) while in Malaysia 3.2 billion SMS messages were sent in 2006 (Kamal, 2007). Text-based messaging is synchronous and creates a social space. When SMS needs to be shared via a larger network, it becomes one-to-many, and this is what defines *Twitter* space.

Twitter is indicative of the rise of social networking sites which allow people to connect and communicate, and as such it is central to our theory of machine space. Where *Twitter* differs from others such as *MySpace* or *FaceBook* is that it is purely text-based in the SMS format of 140 characters with a text entry box asking the simple question ‘What are you doing?’. Based on SMS, *Twitter* is useable via a mobile phone with messages geo-located by typing in your location after the message. As such the data can be mashed and reused an infinite number of times through the Web or visualized within a digital city in real-time. Messages sent via *Twitter* are known as Tweets, and we can illustrate these with the location of Tweets over a 5 minute period in the South of England in Figure 5 in late November 2007 using the *Google Maps API*.

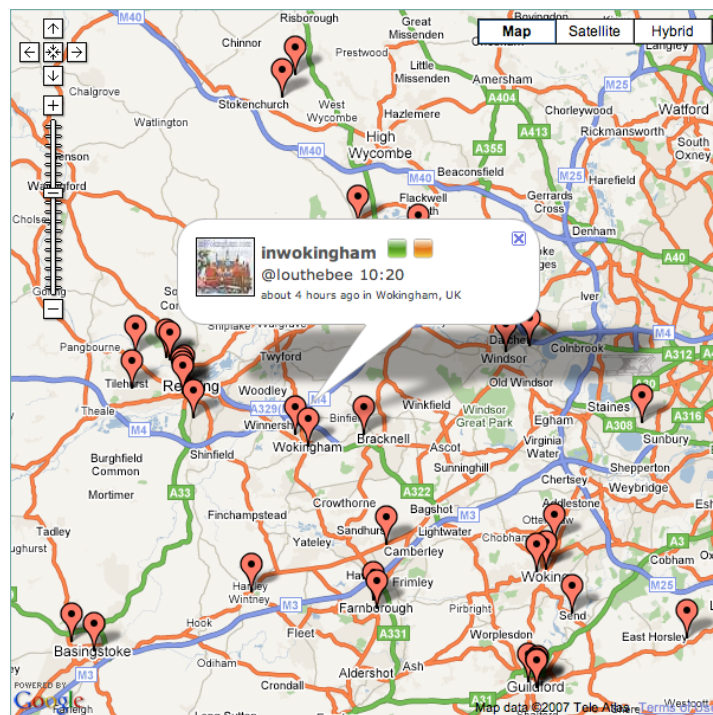


Figure 6: *Tweets West of London*
in South East England at 10-20am, November 27th 2007

Tweets can also be visualized in *Second Life*, the most complete of the current generation of virtual worlds that combines visual, social, informational and perceptual space, recursing the city and which is slowly but surely creating perhaps the first true example of a mirror within a virtual world. But we only use the example of Tweets as one of many relating to streaming real time data in general from the real into the mirror world and thence into the virtual world. Much of this data is and will be locational as individuals become equipped with GPS on their phones and other devices such as PDAs, i-Pods and so on. The prospect of enormous quantities of vocational data beckons and it is these mirror and virtual worlds that in their locational-geographical views will be mobilised to make sense of all this, as *Twitter* is beginning to illustrate.

Second Life and its predecessors such as *ActiveWorlds* have, in the same way as *Google Earth*, also been strongly influenced by Stephenson's (1992) vision from his novel *Snow Crash* where he first describes the MetaVerse: "As Hiro approaches the Street, he sees two young couples, probably using their parents' computer for a double date in the Metaverse, climbing down out of Port Zero, which is the local port of entry and monorail stop. He is not seeing real people of course. This is all part of the moving illustration drawn by his computer according to the specification coming down the fiber-optic cable. The people are pieces of software called avatars" (p.35).

Avatars are an individual's visual embodiment in a virtual world. They provide an all-important visual and social presence in the digital environment. They are the citizens, the occupants, and the commuters of the digital realm. As such they are also the citizens that can occupy, add data and manipulate the digital built environment. The term avatar – for use in terms of digital environments, that is – was first used by Chip Morningstar, the creator of *Habitat*, the first networked graphical virtual environment developed on the Internet in 1985. The term 'avatar' originates from the Hindu religion as an incarnation of a deity; hence, an embodiment or manifestation of an idea or greater reality. Our presence in virtual worlds is usually through the avatar although it can be any object, and in terms of a mirror world like *Google Maps* as in Figure 6, it is the balloon icon. We have already seen avatars in our early examples of virtual worlds in Figure 2 but here Figure 7 illustrates typical avatars in *Second Life*.



Figure 7: Avatars in Second Life

And so to *Second Life* where which we now consider the natural focus for our *Virtual London* model. *Second Life* is a world in which virtual land passes for real dollars and we have been fortunate in gaining the support of *Nature* magazine who have purchased an island in *Second Life* for demonstrating serious science. We have squatter's rights courtesy of *Nature* on their *Second Nature* Island. What we are doing is porting

geographic media in 2D, 3D and through time as streams of online real-time data about the city into this virtual environment. We are fashioning tools to enable us to do this. What *Second Life* provides is the real time context for user engagement with a virtual city through its embedding of mirror worlds. 3D-GIS or CAD software does not provide this content, nor do models embedded in web pages that users can browse and fly through. We need an environment for exploration in which many can interact and fashion the media in diverse ways. We need environments in which we can pose unrelated imagery and content enabling unusual kinds of juxtaposition which users themselves can control and interpret. We need an environment where different kinds of time streams can come together with different kinds of spaces.

What we hear you ask is all this for? Well in our Lab CASA, one of our colleagues is building a tourist information system for Phuket in Thailand using the traditional GIS, planning and decision support which is targeted at decision-makers, planners and tourists themselves. Bringing a great diversity of material together in digital form and co-locating it in a form that resembles the geography of the area is what *Second Life* offers. Moreover it provides an easy entry to space which is attractive and interactive from which users can download material and search for related items of information. This kind of visual space is highly experimental but it offers insights into problems that others may share. We are doing the same for parts of *Virtual London* but we are interfacing this with buildings at different scales and maps which take the scale up to the metropolis itself. Changes of scale are central to an appreciation of cities and *Second Life* enables us to achieve this easily. There is still a major challenge in assembling information coherently and then using it collectively to some purpose but the sheer scale of the environment is such that like *Google Maps* before, millions of users are fashioning a multitude of extensions. We show a piece of our world in Figure 8.

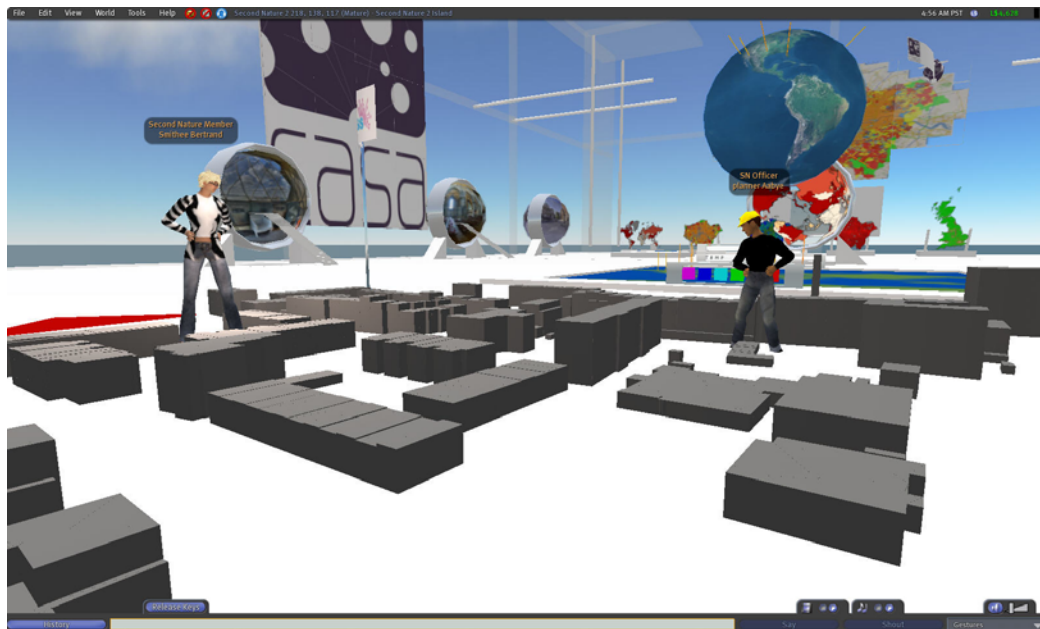


Figure 8: *Scaling the City: Building Virtual London in Second Life.*

Second Life currently represents the most successful social/visual space on the Internet. Launched in 2003 with little more than a few kilometres of simulated computer space, in May 2007, it covers over 750 square kilometres (Ondrejka, 2007) which is roughly half of the size of our *Virtual London* model. Of note is the population which is approximately 15,000 residents logged in at any one time, and thus it has a population equivalent to Ilkeston, Derbyshire, or Troutdale, Oregon (Rolph, 2007). *Second Life* is extremely sparsely populated compared to a real city. Vast swathes of the area are devoid of avatars, much of the being a virtual world forming an empty mirror to the real world. But although the density is low, development is intense in the spirit of Wikinomics as defined by Tapscott and Williams (2006): “Today the Net is evolving from a network of websites that enable firms to present information into a computing platform in its own right. Elements of a computer – and elements of a computer program – can be spread out across the Internet and seamlessly combined as necessary. The Internet is becoming a giant computer that anyone can program, providing a global infrastructure for creativity, participation, sharing, and self-organization”.

Although Linden Labs, the creators of *Second Life*, developed the program, it is the population of avatars that is creating the hamlets and towns that form its 750 square kilometres and its economy. Millions of Linden Dollars change hands every month for the goods and services residents create and provide. This unit-of-trade may then be bought and sold on LindeX (*Second Life's* official Linden Dollar exchange), or other unaffiliated third party sites where real currency changes hands (Linden Labs, 2007). In these new worlds, the population is in flux as users can ‘jack in’ and ‘jack out’, to adopt the terminology of *Snow Crash*. During August 2007, 23 million man hours were spent in *Second Life* time spent by over 974,000 users, an average of 23.6 hours per user. Hof (2006) in *Business Week* states that as the residents spend “... a total of nearly 23,000 hours a day creating things, it would take a paid 4,100-person software team to do all that. Think of it: the company charges customers anywhere from \$6 to thousands of dollars a month for the privilege of doing most of the work ... In other words, your next cubicle could well be inside a virtual world”. This is Wikinomics in action, working inside the mirror as a cumulative workforce, something unseen since perhaps the industrial revolution, perhaps never seen before. People as we write, are grouping buildings and forming city plans, beautifying their virtual plots, buying and selling, or just going about their everyday life inside a machine which is increasingly becoming a mirror to the real world. In Gelernter’s (1991) terms, the mirror world has entered a virtual world which mirrors the real world in part but only in part and provides a sense of interaction between reality and virtuality which is unprecedented. This is a simulacra in Baudrillard’s (1994) terms.

Second Life demonstrates the power of using place within a communications medium, allowing distant participants to leverage real-world metaphors and behaviours to improve collaboration (Ondrejka, 2007). In 1928, Bertrand Russell went on record as saying that “... machines are worshipped because they are beautiful”, but our fascination with them has gone far beyond their physical form. Despite the science fiction of it all in terms of man existing in ‘the’ or ‘a’ Metaverse, it cannot be denied that people are now existing,

trading and communicating inside the machine. Technology acts as a catalyst to change not only what we do but also how we think. It changes our awareness of our self and of one another, of our relationship to and with the world (Turkle, 1984). Perhaps it is ourselves that are recursing into the machine rather than our physical counterparts and containers in the form of the city. Web 2.0 provides the forum on which to engage in such speculations, notwithstanding their apparent far-fetched nature.

Almost a decade ago, Damar (1998) implied that a revolution was on the horizon, the arrive of a 'true cyberspace' that would change the very face of software and our use of computers. Our definition here suggests that the computer is rapidly becoming the most significant of spaces and thus our concept of real geography may indeed no longer be as relevant as in computer space. The notion that we can be anywhere at anytime with anyone changes everything. Ondrejka (2007) calls this the 'collapse of geography' and indeed predicts a redefinition of the nation state with virtual worlds changing the alignment of labour markets and the shapes of large organizations. If real world space no longer matters or matters differently, then reality will indeed recurse into the virtual. Neogeography is set to make the geography of the real world less relevant, and in a sense the Mirror World will be a world where physical location does not matter which is the ultimate recursion.

Informational Space: Augmenting Iconic Simulation in the Real City

When we introduced Bell's (1996) definitions of space, informational spaces were characterised as an overlay to visual space for this is the space in which we communicate and receive information about the city. From urban signage to oral communication, information is communicated in visual space. This is the reality of space, the space that we can overlay with data, augmenting reality and the city with a series of icons. Augmented reality is by no means a new concept. Caudell coined the phrase 'Augmented Reality' in 1990 while at Boeing when helping workers insert and assemble cables into aircraft and we have seen many images of workers augmenting their physical skills through head-mounted displays and eye trackers which deliver pertinent digital information to help them in their physical tasks. Augmented reality contrasts with our mirror worlds we have explored so far for these are synthetic environments while augmented realities refer to situations in which the goal is to supplement a user's perception of the real physical world through the addition of virtual objects (Azuma, 1997).

It is this supplementation, an overlaying of data that mixes realities from the real with the virtual and the perceived that lends itself to iconic simulation. Looking around a city in augmented reality, perhaps via a location-aware portable device, mobile telephone or a head-mounted display, screen information can be overlaid onto the real physical space. For example, looking around a streetscape the device would recognise buildings, transport links, and signage allowing additional data to be streamed in via the network. An example is shown in Figure 9. Such devices, built into light weight glasses are emerging in the market place with mobile telephones being increasingly locationally

aware, paving the way for local, augmented reality services. At the heart of the argument is the desire for information, to be part of a wired society and to feel connected to the city: not only on the social and business level but also in terms of our appreciation of environment, architecturally and naturally, combined with the need to know and query what is around us.



Figure 9: Augmenting the Real City with Digital Information

The information encoded into the locations around us and used for augmenting reality is defined by Sterling (2007) as 'Hyperlocal'. Sterling states that the databases on Web 2.0 are stuffed with geographical co-ordinates: real positions and real distances. So the bodyware I carry in my pocket and travel bag broadcasts its location to any device within earshot. This data will connect us to the city in a manner that will quickly be taken for granted once it appears and becomes widespread in the same way that *Google Maps* and *Google Earth* are now seen as indispensable. A simple current example is *Mediascape*, freely available software released by Hewlett Packard which allows the development of simple location based information applications (<http://www.hpl.hp.com/mediascapes/>). It is described as a "series of composed of sounds and images placed outside in your local area". To see these images and hear these sounds, you need a handheld computer or PDA and a pair of headphones. An optional GPS unit can be used to automatically trigger the images and sounds in the right places. To create a *Mediascape*, you start with a digital map of your local area. Using free software, you can attach digital sounds and pictures to places that you choose on the map which we illustrate in Figure 10.

Going outside into the area the map covers, you can experience the mediascape. Using the handheld computer and headphones, you can hear the sounds and see the pictures in the places the author of the mediascape has put them. The software is currently in

development but provides an insight into how the real world can be easily augmented by users. Move this into Web 2.0 environments as will surely happen and areas of the cities could easily be swamped with media and information. The virtual world will intersect the real world more in the manner sketched a decade or more ago by Batty (1997) in his concept of the computable city. In this way, the virtual world and its mirror gives back to the physical world, completing the loop of recursion in strange and enticing ways. This is then the prospect: of mirror world standing astride both the real and the virtual, of information being recursed into many forms and being made available in diverse ways to people acting as avatars to people acting as themselves but in weird and wonderful environments yet to be invented.

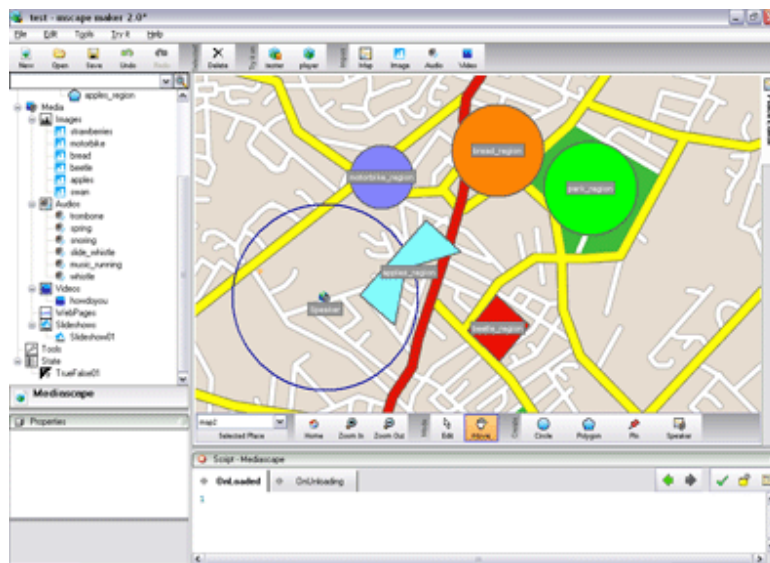


Figure 10: Augmenting the City through the *Mediascape*

Conclusions: Emergence on the Digital Frontier

Future trends are notoriously difficult to predict. **Popular Mechanics** predicted in 1949 that computers in the future would weigh no more than 1.5 tons. The internet is littered with such comments. The founder of IBM, Thomas Watson stated in 1949 that the world would never need more than half a dozen computers. Bill Gates admitted that when he was asked in 1994 when the first internet browsers appeared if there would ever be web addresses stencilled on taxis, he told the questioner not to be stupid. With technology moving on at an ever increasing rate, it would be foolhardy to predict beyond a couple of years. We have not seen, nor are we close to a complete Mirror World but the trends are in place, the price of data capture has dropped, and Web 2.0 supplies the man power which is required to populate the world both socially and in terms of this spatial extent. When Gelernter's (1991) book **Mirror Worlds** was reviewed for **Computers & Geosciences** in 1995, John Butler, the Associate Editor, noted that: "the inertia of the web may or may not prevent extensions to pass the initial limitations of design, it may never leave the page-based, one-way link metaphor that is at its root. A useful tool for

downloading data from NASA, perhaps, and an online encyclopedia (of dangerously variable quality) to be sure, but not the real-time, rich, and multifaceted infospace that Mirror Worlds could be". We shall see. A decade on Web 2.0 and innovations like *Second Life* continue to point the way to this cornucopia of rich and multifaceted infospace.

In 2007, NASA has its own *Virtual Earth* in the shape of *World Wind* and Web 2.0 has produced Wikipedia effectively creating an online encyclopedia, already illustrating the unpredictability of this future in terms of the use of technology. Web 2.0 is changing the ways companies work, embracing the consumer, allowing social networks to build content and therefore add value to their system. In many ways, this combination of ideas, work hours, and mass collaborative efforts is like an emergence on the digital frontier, a bottom up model for an interconnected system of relative simple elements which self-organise themselves into a form of intelligent, adaptive behaviour (Johnson, 2001).

Recent talk is of a merger of *Second Life* and *Google Earth*, *Second Earth*, as articulated by Roush (2007) in **Technology Review**. Populating and spawning systems such as *Google Earth* is almost inevitable given the open nature of the net. It is already possible to link Skype and *Google Earth* via avatars with *Unype*, albeit in a crude manner. A populated digital earth is another step closer to a Mirror World and we envisage a number of competing systems coming into the market place within the next year. The prospects for these are not certain: after all, the pull of a virtual world is the ability to build and create. Where do you build in *Second Earth* when the cities are already virtual and space is at a premium: on the green belt or in the deserts? Perhaps the earth will instead recurse itself into a virtual world, complete with all the functionality of zooming and data query but simply as another object in a wider digital environment. We illustrate our own early experiments of this kind of *Second Earth* in Figure 10 with real-time weather data displayed on a digital globe inside *Second Life*.



Figure 11: Recursing the Earth's Weather into *Second Life*

Embedding a digital earth into a virtual world is perhaps the ultimate recursion. The world will still function as *Google Earth* but it can be cloned, copied and queried over and over again and rescaled to any size. In essence these are worlds within worlds and worlds that can be scaled according to a user's requirements in computer space. It is in this sense that we began this chapter making the shift from the computer in the city to the city in the computer but this presages a much wider challenge of placing our entire world in terms of our social existence into the machine. Perhaps we have moved from the 'Computable City' to the 'City in the Computer' and now stand at the dawn of the 'Computable Earth'/'Earth in the Computer' with all its components of place and space in an effective and meaningful coupling of the virtual and the physical.

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