AN OVERVIEW OF CITY SIMULATION

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Abstract. The present state of development of city simulation is outlined, including the relationship between the physical city and the virtual city and the traditions and history which lies behind the development of computer simulations of cities.

1. Introduction: Real and Virtual Worlds

We begin with the premise that all cities will (and to some extent already do) routinely exist in both ‘real’ and ‘virtual’ forms. The two complement each other. Largely they are seen as, and operate as, independent entities, but the two overlap and come together at interesting points.

The physical city will continue to have buildings, roads, traffic, and people. It is where we meet people, do business, eat and drink. Though buildings might come and go, in larger terms the physical city changes slowly. This ‘real world’ is always multisensory, includes great detail, and much of it is irrelevant to our immediate needs.

The virtual city (Mitchell’s (1996) ‘city of bits’) connects us with networks, computers, software and representations. It generally claims and has no necessary relation to the ‘real’ world; the physical location of the necessary computers and human support staff is irrelevant to the way this world is presented.

Virtual world representations of the real world such as city simulations are
special cases. These are models in the virtual world which represent places in, and aspects of, the real world. Some model physical form while others concentrate on social and physical processes. Sometimes the models are ahead (modelling future structures, places and organisations), sometimes behind (deliberately modelling the past or simply not up-to date) the real world. A central theme in the virtual modelling of cities is the greater understanding of the past and present of the physical city, and the increased ability to manage the future, that is made possible by this modelling. Common characteristics are abstraction (using representations which are more symbolic/abstract than the real world), enhancement (using representations which emphasise/enhance aspects of the real world) and simplification (using representations which act ‘as if’ the systems and features of the real world were less complex than they are).

The edges and slippages between the physical and virtual worlds are particularly interesting: how the ‘real’ interacts with the ‘virtual’; how the ‘virtual world’ informs us about the ‘real world’; and how our cognitive understanding about one is influenced by our exposure to and understanding of the other.

2. Representing Cities: A Historical Overview

The computer simulation of cities has emerged from several traditions: databases, mapping (through geographic information systems (GIS)), model making (through computer-aided design (CAD)), visualisation (through photographic and digital imaging), and process modelling (through mathematical models). In this section we combine a brief historical review of these traditions with some examples of city models which lean towards one of these origins.

2.1 CITY DATABASES

The earliest city databases were simply lists of people and assets, often for taxation purposes. With the advent of computers, comprehensive databases emerged with the great advantages of search and cross referencing capabilities. Regarding cities as data sets, 2D and 3D forms are instances of data.; for example, in the US internet business index ‘Big Book’ location in a rudimentary ‘city model’ is an attribute of the business.

2.2 CITY MAPS

A map is a symbolic representation of the world drawn to an accurate scale, using a set of uniform symbols. The earliest maps, particularly during the
medieval period, were aerial views which showed the geometric form and appearance of the city as well as its street layout. Accuracy was often sacrificed in order to ensure that all the finest buildings and monuments were shown and the artistic and symbolic qualities of the work were at least as important as its objective status. Accurate surveying, standardised sets of symbols, and (from the late nineteenth century) cheap offset lithographic printing resulted in the 2D map becoming the standard way of representing cities. The paradigm of the map is now so powerful that it tends to blind us to other forms of representation.

With the advent of computers, analytic tools have been added to the map. GIS developed in the early 1960's (Ian McHarg's influential book ‘Design With Nature’ was published in 1969, pioneering the development of map overlay techniques), and became generally accepted as a spatial data storage and analysis tool during the 1980's and the early 1990's (Maguire et al 1991). Multiple 2D maps are linked to each other and to non-map database information which is indexed by plan elements.

A 3D block model of the City of Adelaide, constructed by bringing together 2D GIS data on road centre lines, building footprints, sewer and water pipes, electrical cables and ducts, precinct boundaries, zoning boundaries, and a digital elevation model, is directly derived from this mapping/database/GIS tradition. Transforming 2D GIS data into a 3D version entailed attributing third-dimension values to each spatial feature, using data on the number of floors for buildings and heuristics on pipe depths; the result is simply a 3D visualisation of existing essentially 2D data.

![Figure 1.](image)

*Figure 1. (Left) The Adelaide City Model, essentially a ‘block’ model mixed with digital photographs, and (Right) a subsurface view of the model showing pipes.*

It is combined with aerial photographs of the surrounding park lands, suburbs and street network, and of the major squares in the City, and viewed
with interactive software originally developed for visualising ore bodies in the mining industry.

2.3 CITY MODELS

Although architectural models have been popular since the Renaissance, there is no similar history for physical models of cities. However, some have been built, such as the 1:500 wooden model of Bath that was constructed in 1972 as a way of illustrating comprehensive new road proposals designed to restrict car access to the town centre. Over the past thirty years CAD systems have allowed the creation of three-dimensional architectural models which can be as accurate as necessary and, once created, can be viewed from any position. In this tradition the computer urban model is constructed in essentially the same way as a building, using layers and objects and appropriate simplifications but always representing 3D form in all three dimensions. A particularly complete example of such a model shows proposed redevelopment in central Berlin, created by InterMedia and used as a part of the public exhibition in the ‘Info Box’ in Berlin.

The Bath Computer Model was originally constructed as a CAD model to be made available to architects and urban designers and used as part of the formal planning process in the city. It was constructed using an industry standard CAD package (AutoCAD) and is organised as some 160 sub-blocks, each of which has been modelled at four levels of detail. The basic model consists entirely of geometric faces organised into layers which have colours applied to them. Increasingly, models are seen as interactive and universally available. Software has since been written to translate the CAD model of Bath into VRML (Virtual Reality Modelling Language) which has then been customised to allow alternative schemes for a site to be called-up interactively and objects, such as trees and street furniture, to be inserted in real-time. The fact that VRML was designed to run within a World Wide Web Browser, such as Netscape, offers some significant advantages over more conventional VR software. The browser is available at minimal cost, the software is platform independent and models can be transferred across the Internet (although capacity limitations can mean that it takes a long time to transfer a model of any size). Advantage can also be taken of information that already exists on the Internet and links made between objects in a city model and WWW sites. Part of Central London that has been modelled using this approach where masts indicate live sites and where residents and businesses can add information to the model. In this way one begins to see behind the facades to the activities which underlie city life.
2.4 CITY VISUALISATION

City visualisations (emphasising form and appearance) derive from traditions of drawing and painting, photography, film and video. One of the earliest models of Adelaide is a ‘diorama’, a 360-degree photographic panorama taken in the late 19th Century. Computer databases and hypermedia can index and link photographic, video and related images.

Visualisation or imaging software has been developed largely for the entertainment industry. Compared with architectural software, they are easier to use, better at making previews, and are a good compromise for animation and virtual reality (Mayer, 1997). As far as possible, they use bit-mapped images (taken from photographs and generated textures) rather than constructed 3D geometry to create the sense of 3D form.

Two ambitious city simulations based on visualisation software are those of Los Angeles and Berlin. UCLA’s ‘Virtual LA’ aims to include ‘a real-time simulation model of the entire Los Angeles basin. This model will cover an area well in excess of 10,000 square miles and will elegantly scale from satellite views of the L.A. basin to street level views accurate enough to allow the signs in the windows of the shops and the graffiti on the walls to be legible. It is estimated that when complete this model will exceed 1 terabyte in size. It will be maintained on a large multi-client server ... which will allow multiple simulation clients to fly, drive and/or walk through the Virtual L.A. Model simultaneously’ (see web page, address at end of paper).

Art+Com’s interactive model of Berlin is similarly ambitious. In its software an arbitrary amount of city can be represented in the database, and parts of the city are loaded ‘as it gets there’ in an interactive fly-through. Whole city
blocks switch to individual buildings as the view approaches.

Figure 3. (Left) Virtual LA and (Right) Berlin CyberCity. Sources are web pages (addresses at end of paper)

Mixing 3D modelled and 2D bit-mapped ‘simulated’ images of cities with ‘real’ (photographic or video) images is common. For example, a video promoting proposed inner city housing in Adelaide begins with a bird’s eye view (a very high flying bird) of the whole city, using a computer model. The view zooms in towards the housing area, switching to a more detailed computer model and from this model to ‘real’ at the edges, where the real world exists to be photographed. Interspersed with modelled views of unbuilt houses are video clips of real people drinking real coffee in real cafes. Views over the modelled balustrades of unbuilt balconies look towards the real trees of the Adelaide park lands and background of the Adelaide hills. The detail and animation of the real carries over to the virtual, breathing life into the visualisation.

2.5 REPRESENTATIONS OF CITY BEHAVIOUR

Simulations of dynamic phenomena in cities derive from general system theory and mathematical modelling, emphasising the behaviour of systems over time with no regard to appearance. Early examples which attempted to represent, and hence predict, urban behaviour were constructed by members of the Chicago School of Urban Ecology in the 1920 and 30s. For example, Park and Burgess (1925) developed a model based on land values where the highest price land was at the centre and this declined the further one moved out. Such models best described rapidly developing cities where there were few encumbrances to unconstrained growth within a free market economy. By the late 1940s, growth in private car ownership meant that existing cities could not cope with the increased traffic. This led to the instigation of large
scale transportation studies and the development of mathematical models of traffic flows. Early models concentrated on trip generation and, although these appeared successful, they ignored land use patterns and it was not until the mid-1950s that a more integrated approach was adopted (Mitchell and Rapkin, 1954).

The first generation of computer urban simulation models were designed and implemented in the 1960s as part of large scale land use and transportation studies in major metropolitan areas in North America. Although they provided some useful insights many were too ambitious in data requirements and/or computer time. As Batty (1976) put it: ‘Many argue that such models are so poor a representation of reality that they are often irrelevant to the problem in hand, whilst others argue, in a similar fashion, that urban modelling is a worthless task, for reality can never be described numerically. Both these views contain an element of truth. Yet the purpose of any model is to simplify reality, thus leading to greater understanding and to means whereby experiments can be made on the model in the quest to explore both the present and the future.’

Models for predicting environmental processes in cities are still not well developed. The pattern of sun access and shading as the sun moves through the sky are easily modelled in most CAD systems, although the complexities of sun movement are not always correctly represented. Models of the thermal and aural environment in urban areas are weak. For example, models for the prediction of urban air temperatures which account for the effect of urban geometry and density on intra-urban variations of air temperature operate over very small parts of the built environment; a street corner, rather than a precinct (El‘Nahas and Williamson, 1997). For air movement, rather than work with digital air-flow models over very complex environments it may be easier to use a 3D urban model to build a block physical model with numeric control machines, use that in a wind tunnel, and record the data back in the digital model representation. Of other behaviours, transport models are the most developed.

3. Cognitive Models and City Simulation

Kevin Lynch (1960) was concerned with the city as social space and, in particular, the ways in which we construct a internal cognitive model of the city. Lynch’s key concept was that of imageability, those properties of a city that allowed the individual to construct a clear image, or internal model of it, which they could then use in their interactions with the city. This image was made up of a number of elements, including objects such as landmarks
or key buildings, edges, which marked a change in character or function, and paths which defined routes through the city. What he produced was not a ‘model’ in the traditional sense but a way of looking at the city which acknowledged the importance of its visual characteristics and the fact that our perceptions of a city are central to its success.

Hillier and Hanson (1984) studied historic cities of the kind admired by Lynch and found that their ‘organic’ development led to remarkably similar street patterns. These, they argued, were not a function of the economics of market forces but of simple social mechanisms related to how people prefer to use cities. All the routes in a city can be represented as a line map which can be analysed in a computer and the interconnectivity of the roads can be calculated. Their ‘Space Syntax’ simulation of the urban environment can be used in a predictive as well as a retrospective way, explaining why certain places ‘work’ and are lively and safe while others are underused and neglected and attract vandalism and anti-social behaviour.

The notion of cognitive models of cities applies to virtual as well as physical cities: “the construct is valid whether the information it portrays comes from real or symbolic sources. This validity becomes more important as virtual reality and simulation technology extend our cognitive space into interactive environments” (Anders 1997, p18). Moreover, our cognitive model of one impinges on the other. Maps, and computer models, change our view of the world. A powerful example is provided by Art+Com’s demonstration of interactive ‘global travel’, shifting from image to image (using models at different levels of detail, and aerial and satellite photographs) up and away from a street in New York, to the precinct, to the city, to the east coast of the USA, and then over the Atlantic to the coast of Europe, to Germany and then Berlin, homing into the interior of Art+Com’s own building. The demonstration of continuity and connection modifies one’s view of the world and distance.

4. Discussion

The international scene in city simulation is one of many approaches and many kinds of models. There are both top-down (strategic decisions to build integrated city models) and bottom-up (aggregations of visual models of individual buildings, GIS data, traffic models, drainage models, etc, to create a city model, but with lots of gaps) processes in constructing city models, and in many places both are happening concurrently. Their users include geographers, economists, planners, services and traffic engineers, environmental engineers, architects and urban designers, emergency services,
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A tour of tourism and public relations.

An integrated city model is about making and understanding connections between phenomena, linking visual and non-visual, static and dynamic, descriptions and data. Presenting urban information typically involves hypermedia, image databases, and interactive or preconfigured animation. “Included are quantitative, qualitative and visual information such as maps and air photos, explanatory diagrams, movies and pictures of key places and features, GIS maps and land use suitability models.” (Kellett et al 1997 p299). Characteristics of computer modelling are being able to mix the realistic and the abstract in sophisticated ways, and being able to show representations of the past, present and possible futures; the map and model have become multidimensional in space and time.

The availability of city simulations and data influences the mode of work and standing of the users (Day and Radford, 1995). The ability to represent the interaction of design decisions typically made by engineers and architects/urban designers, for example linking visualised dynamic phenomena with physical form environment (energy, climate, noise, and water management, transport), opens new possibilities for informed collaboration. To develop the field further, we need better understanding of appropriate abstractions and notations. We also need more automatic data generation, ‘driving through the city with a scanner’ as it has been expressed (Mayer, 1997). We need ever-increasing computer processing speed in order to build and operate interactive models, and to be able to switch between different representations. We need to understand better the social and cultural processes surrounding the use of urban simulation in planning, urban design, etc, through reflective action.

We also need a better understanding of how to link and slip between physical and virtual worlds, exploiting the best of both. Anders (1997) writes of how virtual work environments are quicker and easier to change than physical environments, and how mixing them can lead to more economical and efficient working environments. The same applies to cities as a whole.

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References


Web pages


Bath model http://www.bath.ac.uk/Centres/CASA/

Berlin model http://www.artcom.de/projects/stp/WWWpaper/CyberCity.html

Los Angeles model http://www.gsaup.ucla.edu/bill/LA.html