Visualising City in Change with the MEDIUM Platform

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Abstract. Work on a methodology that attempts to deliver a dynamic urban information system for visualising city in change is presented. We have developed a Multi-tier Extensible platform for Dynamic and Interactive Urban Modelling (MEDIUM) in connection with a large-scale historical urban study programme that investigates the history of the City of Sheffield. The MEDIUM platform shows some new properties that could address the limitations observed in conventional static urban modelling. We consider that 3D virtual city models can be created along a chronological axis and the time dimension of each model segment can be registered in such a way that the 3D models of different times can be brought together under a unifying visualisation platform. This will allow a visual understanding of how a city may have evolved to develop. To date, we have applied the MEDIUM platform to real city datasets and produced examples that allow us to examine what effects of urban visualisation could be achieved through the dynamic user-centred approach.

Keywords. Dynamic urban modelling; virtual city; urban study, VRML; Web.

Studying city in change: The Sheffield Urban Study programme

Given the recent advancements in computing technology, it remains a considerable challenge to establish an effective approach to visualising how a city has evolved over time. In many fronts, we are now more capable than before of producing graphically sophisticated 3D models of city fabric of a fixed time in the past or at present. The models are not much useful to our understanding of how cities have changed as real cities are always in a state of flux. In this paper, we present our recent research into a methodology that attempts to develop a dynamic urban modeling platform for visualising city in change. In the past two years, we have experimented with a Multi-tier Extensible platform for Dynamic and Interactive Urban Modelling (MEDIUM) in connection with a large-scale historical urban study programme—Sheffield Urban Study that investigated the City of Sheffield.

In our view, the experimental MEDIUM platform presents some interesting properties that could address the limitations observed in conventional static urban modelling. Conceptually, we consider that visual models of a city can be created in a chronological axis and the time dimension of each model segment can be registered so that city models of different times can be brought together under a unified visualisation framework, allowing visual understandings of how a city may have evolved to develop. To date, we have applied the MEDIUM platform to real city datasets and tried out specific examples showing what visualisation effects could be achieved through the dynamic approach.

We shall first introduce the origin of the research: a large-scale urban contextual study that preceded the development of the MEDIUM platform. The Sheffield Urban Study programme was originally set up with two aims in mind (Blundell Jones et al. 1999). The first was to enable us to better understand the shape and layout of the city by documenting its growth, in terms of street layout, built fabric and social content. The second aim was to provide data for the understanding of an urban context where a new building might be proposed. It was our conviction that an architect needs to understand the history of a site before making a proposal, so that he/she can understand the place that is being changed through the intervention. For both aims it was essential to operate at scales that could relate the single building to the rest of the city.

Following an urban grid introduced at the beginning of the urban study (Figure 1), historical records of 41 “squares” (a square denotes an area of 200m by 200m) of the city have been systematically collected into the Sheffield Urban Study Archive (SUSA). Each square contains a variety of records including historic maps, physical scale model and text/photo documents on the status of the urban fabric in around Year 1900 when the city reached its peak in steel-making industry.

The simple urban grid proves to be a useful analytical tool as used by all the students partaking in the urban study for three consecutive years (1998-2001). It first divides the city fabric into a size that a group of four or five students could

Figure 1. The urban grid applied by the Sheffield Urban Study programme (photographed and edited by Peter Lathey, School of Architecture, University of Sheffield).

work with in about six weeks. Secondly, it provides a framework for the SUSA resources to grow geographically as the programme continues. Finally, the grid labeling (i.e., A1, B2, C3, W8 etc) becomes a means of how the archive materials are located and accessed physically.

Apart from generating the physical database of a high quality, the Sheffield Urban Study project seems to have achieved its own pedagogical objective: the students learn how to conduct urban and architectural research using historical maps and local archives in a systematic and collaborative manner. Given the experiences of partaking the urban study project, a proposition for students to consider in their future urban design projects is that a contemporary design cannot be fully grounded without a firm understanding of the past of the place.

Based on the results of SUSA, a separate research project was launched later to investigate how the physical archive established by the urban study could be turned into electronic form allowing for wider access and longer-term data preservation. To search for a suitable methodology of digitisation, we began by reviewing some of the previous attempts at applying computer modelling to the studies of historic and contemporary cities.

Reconstructing historic cities: some precedents of computer modeling

The Bath Model

The Bath Model was created by the CASA group at the University of Bath. The aim of the project was to visualise the changes in the City of Bath and how the city was originally constructed at the Roman and Medieval periods. The Bath model was initially built with 3D modelling and texture mapping in AutoCAD, and was subsequently converted into a single VRML model. The model covers a square of 10km each side with texture-mapped terrain around the city and the Bath Abbey in some detail (http://www.bath.ac.uk/Centres/CASA/). The model was organised in four levels of detail with data links to images and texts on the city and building history. The Bath model has been used by the city's planning authority for development control and public consultation on future city developments (Day et al. 1996; Bourdakis and Day 1997).

The Glasgow Directory

The Glasgow Directory was developed by the ABACUS group at the University of Strathclyde (http://iris.abacus.strath.ac.uk/new/gintro.htm). The system was intended to present the city of Glasgow in 3D form with architectural details and a searchable citywide database of her important architectural heritages (Ennis et al. 1999). A variety of online resources are provided, including 3D volumetric models (now in VRML 2), digital photos of architectural interiors assembled in QuickTimeVR™, a map for browsing and retrieving the VRML models, and a search engine for its database of significant buildings of the city. As on the Web, the Directory now hosts a total of 47 separate VRML models, covering an area of about 25km2 accurate in height and plan. However, the effect of conveying the true city form is diminished to a certain extent doe to that most buildings in the models are without roof forms. Nevertheless, the Glasgow Directory has been used by developers in visualising proposals in the context of the city and in promoting the city and its architecture heritage via the Web.

Virtual Dublin

The Virtual Dublin project, developed by Hugh McAtamney at the Dublin Institute of Technology, shows a virtual environment around the area of O'Connel Street in Dublin City (http://www.dmc.dit.ie/guests/eirenet/eirenet/pages/vrdublin.htm). The Web site seems intended mainly as an online tourist information guide for introducing the location of hotels, how close shops, and banks are to the hotels, and where the main cultural heritage attractions are. The virtual street was created by 3D modelling and texture mapping in VRML format, in which one can walk through with accompanied sound clips presenting some urban acoustic features. Data links to texts on local history of buildings, places and events are also provided along the focal points in the virtual world.

Virtual Historic Museum of the City of Bologna

The WWW Virtual Historic Museum of the City of Bologna project is another project of employing multimedia and VR technologies to recreate the historical evolution of the City of Bologna. The project intends to "allow visitors to look back into time 'witnessing' the historical and urban development of the city from the end of the first millennium to the city as it is today" (Guidazzoli and Bonfigli 1999). This was achieved by adding a temporal interface into the Virtual Bologna in the form of a sliding bar with which viewers can operate to switch among different virtual city models representing different historical periods (Bonfigli et al. 2000).

"Virtual Reconstructivism:" development of the MEDIUM platform

There are other projects on computer-based modelling of cities that cannot be discussed further here due to limited space. Considering how conventional city modelling may be improved to overcome some of the limitations as seen from the precedents reviewed and how the resources gathered in SUSA could be best converted into digital formats accessible through multiple routes, we put forward an alternative methodology called "Virtual Reconstructivism." We think that dynamic urban modelling should be developed for our purpose and it can be defined in terms of three basic urban data creation and processing steps: Construction, Deconstruction and Reconstruction.

Construction. Urban fabric, spaces, events are surveyed and recorded on some file formats, depending on the specific mapping, modelling, or authoring tools (packages) used. Types of urban data (models, maps, documents, drawings, images etc.) are said to be constructed by urban modellers in either open-source or proprietary data formats.

Deconstruction. The urban data sets constructed in certain data formats or schemas are deconstructed into individually identifiable rudimentary code sets according to a geo-referencing and naming method. Data "deconstructors" are defined by rules according to which the peripheral parts of a data file representing an object, space, event or phenomenon are removed, leaving the rudimental data entities that can be recombined when recalled.

Reconstruction. Digital representations of urban fabric, spaces, or events are reconstructed in response to users' spatial-temporal interests and choices of urban modelling operations. Data "reconstructors" are defined by rules according to which any number of single data entities or rudimentary code sets can be assembled into syntactically well-formed data formats.

We think that a digital urban modelling platform based on the combined Construction-Deconstruction-Reconstruction processes will achieve an important separation of developers' urban data development from users' retrieval. The separation ensures that user retrieval of urban data is no longer restricted to how the data were created by data developers adopting some schemes of spatial and/or temporal division. An immediate implication of Virtual Reconstructivism is that the digital resources, such as interactive city maps or 3D models, are not deposited as items of pre-determined locations and boundaries; instead, users will be able to receive urban data content assembled on the fly by the data server according to the users' specific spatial and/or temporal criteria expressed in real-time.

Following the Virtual Reconstructivism conceptual framework, we have developed a Multi-tier Extensible platform for Dynamic Interactive Urban Modelling (MEDIUM, Peng et al. 2002a). In short, the MEDIUM platform is of a three-tier architecture consisting of the following (Figure 2):

• Back-end tier. Urban fabric, spaces, events are surveyed and recorded on some file formats, depending on the specific mapping, modelling, or authoring tools (packages) used. Types of urban datasets (models, maps, documents, drawings, images etc.) are constructed by urban modellers working with particular data creation and maintenance schemes;

• Middle tier. The ability to respond to user-centred retrieval in real-time can be fulfilled by a cluster of Common Gateway Interface (CGI) programs/scripts hosted by a Web server. The CGI scripts are designed to process user requests and then generate urban data content accordingly by accessing the recourses stored at the back-end repository; and

• Front-end tier. End-users will be allowed to specify a geographical area and/or a historic period of interest when retrieving combined urban datasets including 3D models. Interactive city maps can be developed and deployed to serve as user front-ends supporting user-centred selection and dynamic retrieval.

Based on MEDIUM, the Sheffield Urban Contextual Databank (SUCoD) (http://sucod.shef.ac.uk) has recently been implemented as a Web-based urban information and modelling system for hosting digital SUSA using a

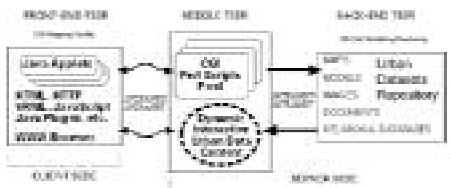

Figure 2. The three-tier architecture of the MEDIUM platform.

combination of existent technologies (Peng et al. 2001; Peng et al. 2002b). In terms of providing an effective instrument for digitising the SUSA resources and making them accessible over the Web, SUCoD seems to have performed satisfactorily. With the flexibility and dynamism permitted by MEDIUM, we also found that SUCoD could be easily extended to serve another purpose: visualising city in change. Although SUSA currently contains no datasets on the contemporary city fabric of Sheffield, SUCoD can be brought up to date as soon as new datasets are acquired by further stages of the urban study survey.

Visualising city in change: an initial experiment

A small set of MicroStation 3D model of the Sheffield City Centre of Year 2000 was kindly made available to us by the Building Design Partnerships (London) for research purpose. With the datasets of different years, we could demonstrate how to perform visual simulation of city in change with SUCoD. Firstly, the Java-enabled interactive maps are built according to the 1900 and 2000 Ordinance Survey. The two object-based interactive maps of different years are then deployed through a common graphical user interface provided by the same Java applet (Figure 3). In theory, we can build many more layers that correspond to other years or historic periods. By reading the over layering maps, users of SUCoD could perceive how the city fabric has evolved during the period of time in two dimensions at least.

The Java-enabled maps also act as a front-end for users to select an area of interest and retrieve a 3D model (in VRML 2) of the selected area. The same operations of select and retrieve can be applied to the Java maps of different years, and the users will then be displayed with the VRML models of the temporal and spatial location and boundaries as requested. Furthermore, SUCoD is able to keep a track record of user retrievals taking place during an interactive session. By invoking the “LIST VRML” function, the user will be displayed with a Web page showing all the VRML models retrieved from SUCoD (Figure 4). On the page, all the VRML files listed can be further selected individually and combined to form a multi-stratum VRML world.

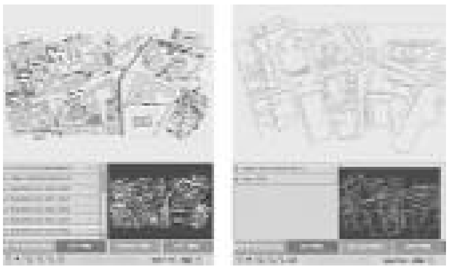

Figure 3. SUCoD's Java-enabled maps showing a map of Year 1900 (left) and a map of Year 2000 (right) of the same city area on two layers accessed through the drop down menu "Select File."

With these online facilities, the user can construct a VRML world containing 3D models of Year 1900 and 2000 of the same geographic location and boundary. Finally, each VRML stratum is associated with a “touch sensor” that can be activated to turn on or off the model during 3D navigation. Figures 5 and 6 show an example of how the Barker's Pool area has changed as seen from some common viewpoints in the VRML world (as registered in exact X, Y, and Z coordinates). Note that users can navigate to any viewpoint to perform visual comparison of VRML scenes as revealed in the two historical model strata. Again, in theory, a VRML world can contain many more strata of 3D models corresponding to other historical periods.

Figure 4. A HTML page dynamically constructed on SUCoD showing the history of a user's VRML model retrieval during an interactive session. All the VRML files listed can be selected individually to construct a multi-stratum VRML world by pressing the “Submit” button.

Conclusions and further research

Figure 5. Barker's Pool in 1900 (left) and in 2000 (right) as seen from a common viewpoint in the sky.

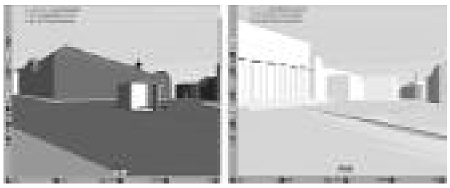

Figure 6. Barker's Pool in 1900 (left) and in 2000 (right) as seen from a common viewpoint on the ground as registered in the same X, Y, and Z coordinates of the virtual world.

The Sheffield Urban Study programme is the first attempt at systematic survey of the city's past that is gradually disappearing under modern and contemporary urban developments. The urban contextual resources gathered are intended to form a scholarly archive for future references in architectural design and research. Digitization of the archive is seen inevitable when considering its long-term growth and accessibility. An experimental generic platform MEDIUM has since been developed to address some of the limitations observed in previous applications of computer modelling to visual simulation of city form.

As a specific implementation of MEDIUM, the SUCoD system was developed by populating a small portion of the converted Sheffield Urban Study datasets. We think that SUCoD has two innovative features: (1) allowing sustainable progressive system growth both in terms of the scope of the urban data and the online mapping/modelling facilities, and (2) supporting user-centred dynamic retrieval that correspond to the user's specific spatial and/or temporal interests expressed in real-time.

It is also found that an urban contextual information system like SUCoD can be used to visualise how the city form has evolved over time by performing visual comparisons of 2D maps and 3D models displayed simultaneously through multiple content layers and strata. Using limited datasets corresponding to two particular historical periods, we were able to demonstrate how visualising city in change could be performed on SUCoD.

It should be noted, however, visualising how city form and urban spaces may have evolved over time is a complex task that demands other kinds of urban information modelling and interpretations. For instance, to better understand changes in the underlying structure of city form one would perhaps require visualisation of the historical development and distribution of building typology in that city. What has been achieved in our present study was a facility of visual comparison of historical city forms represented in simple footprints/volumes of buildings, streets and terrains. Further research and development is required to really try out the extensibility of SUCoD to experiment with other Web-based urban visualisation facilities tailored to other types of city datasets.

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