Rapid Urban Modelling

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Abstract
We describe a system that allows the rapid creation of virtual urban models. We describe how this system can extract 3D model information from Ordnance Survey maps by using a rule-based modelling approach and a parameterised description for common buildings. We also give ideas about how this system could be extended to add detail to models generated from aerial photographs and to include historical events within the model. Finally we show how the models can support changes in level of detail and compression.

Keywords: urban modelling, virtual heritage, virtual reality, model compression, urban primitives

1. Introduction

The task of producing urban models rapidly for Virtual Reality and Virtual Heritage is becoming increasingly important. This is especially true of large scale urban simulations, which will require highly detailed environments locally and less level of detail for distant buildings. An example of this in Virtual Heritage[1] would be an interactive historic ride through a city. The simulation would allow the user to investigate the environment at will and move through history to see the changes that have taken place over time. Each building and structure would need to be detailed enough to create an immersive feel, because the user of the simulation can guide themselves around as they wish.

The task of modelling a city, using traditional manual methods, to a high level of detail, which also contains information about changes over time, would be a very slow process. The process normally starts with modelling the most interesting areas; the cathedrals, churches, castles and public monuments etc. After these interesting areas have been modelled, one is left with the task of filling in the less interesting areas which contain the everyday vernacular[2] buildings. This presents a problem since around 90% of urban areas contain buildings of a vernacular variety.

The normal method of modelling these uninteresting areas is to produce a number of vernacular building models and place these around the urban environment manually. The problem with this method, however, is that it tends to give an artificial and clean look to the model. Most buildings, even if they are of the same design and style as each other, have slight differences which give them an individual look.

The system we describe is based around the task of rapidly filling in the less interesting areas within the model in such a way as to produce a realistic feel and save time and money in the modelling process. In this paper we show how our system can take simple 2D plan information, such as that given by a map, and, using architectural prototypes, we can rapidly create a usable 3D model of an area. In some ways this approach mirrors that taken by Yessios[3] for planning streets. The differences are in the degree to which prototypes are fitted to known data for the real site.

2. Rapid Urban Modelling

Our rapid urban modelling system generates vernacular buildings for populating uninteresting areas within an urban model. Each building is described by a set of parameters (Table 1). These parameters are used to create the 3D model of the building. The parameters for each building are constrained by known rules about English architecture[2, 4].

The first and most important set of parameters for a building is its outline (walls) as well as the orientation of its front facing facade. In the current system this information is extracted by tracing the outline of the buildings from a digitized Ordnance Survey (OS) map. Using this information,

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Style	Georgian, 1790
Roof	Hipped, Slate
Chimney	2
Layout	Double-fronted, Double-pile
Window	Double-hang sash, 3x2, Flush
Brick	Flemish Bond

Table 1: *Example parameters of a Georgian style house*

combined with scale information, it is possible to determine the approximate type and layout of the house; terrace, detached and semi-detached etc., and an approximate internal layout, whether it is 1 or 2 rooms deep and whether the door is likely to be off to one side or in the middle.

Another important parameter used to constrain the building model is its age and style. An example of this would be a building from the 1790s in the Georgian style. These two parameters are then tested against known rules about English architecture to constrain other parameters used for the building. For this example a typical rule would be that based on the tax of bricks, which was introduced in 1784 and lasted until 1850. This would mean the weighting factor for brick as the main building material would be lower than that of stone or external plaster.

Other important parameters deal with the construction of the roof. The roof's initial shape is chosen depending upon its shape and outline and its proximity to other buildings. A terrace roof, for instance, would be joined to its neighbours. The roofs construction is based on a standard set of styles that are built into the system; Gabled, Hipped, Half-hipped, Mansard etc. Other parameters, are then used to constrain the roof, Georgian Style buildings, for example, favoured Hipped style roofs over Gabled style roofs. Also Georgian roofs were normally of a low pitch.

The placement of features such as windows, doors and chimneys is possible when the key parameters, described above, are known. Windows, chimneys and doors are placed, in keeping with the style of the building, using information about the internal structure.

The automatic setting of parameters is carried out in a systematic manner. Once the outline of the building is known, the system will use this outline, along with the outline of nearby buildings and other factors, such as the proximity to a cathedral, to decide upon an age and style. It will then traverse the decision tree picking new parameters on the way using a set of architectural based rules. While it is picking the parameters, more constraints will become available to reduce the number of choices within the decision tree.

Once all the parameters are known, the modelling system automatically creates a VRML model of the urban environment by stitching together the appropriate primitives and material textures.

The model produced is not an exact reconstruction of the urban area, just a similar reconstruction of an area with the same layout. For most large-scale urban models it will not matter that certain areas of the model are not exactly the same as the real thing, only that they look like they could be, thus maintaining a sense of reality. Manual intervention could of course be used to add or merge with hand-crafted models of key buildings.

3. Results

An initial test for the system was to model the Bethel Street area in the city of Norwich, UK (fig 1). Before 1960 this site contained excellent examples of vernacular architecture, being mostly composed of Georgian and Victorian terrace housing. In 1960 these buildings were demolished when the site was re-developed to make way for a new library. This library burned down in 1994, but a new one is planned for the Millennium. The new library will include a visitor centre, using virtual sets and entertainment based of the heritage of the region, which will show how Norwich has changed over the years. The library site itself will form an important part of Norwich Virtual City[5].

The initial models generated by the system are promising, requiring approximately an hour of manual input. The reconstructed VRML model of Bethel Street (fig 2) is simple but shows that the current parameter settings do produce a realistic grouping of building styles.

Figure 1: *Bethel Street Area in Norwich. Taken from the 1914 Ordnance Survey map.*

4. Conclusions and Future Work

A number of systems have been put forward[6, 7] for the automatic extraction of urban models from aerial photographs. Systems such as these can produce approximate urban models, walls and roofs. However, these rough models are of little use on their own, and usually require the addition of extra details using a modelling package and/or the addition of texture maps[8]. An area of research which has had little attention

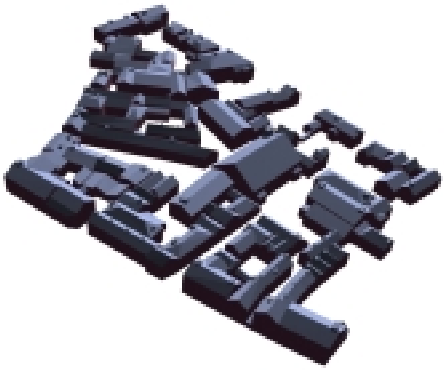

Figure 2: *Reconstructed Bethel Street.*

is that of automatically modelling a house with just an outline, such as that given by a rough model, an area which is directly addressed by our system.

The system has a lot of potential for being extended to extract models from aerial photos by adding on a system such as that being developed by Fischér et al[7]. Their process of building extraction could be added to the start of the process to extract the basic shape of the buildings. These basic building shapes could then be used as a guide to the creation of more detailed building models.

We plan to expand the current system to cope with different building trends and styles from around the world. At the moment the system is tailored towards English building styles.

We intend to extend the system to allow for the automatic extraction of the 2D plan information from OS maps. This is possible due to the simple line art nature of the plans. Recently OS maps have become available in a computerised vector format, allowing the information to be extracted directly.

Automatic selection of the building parameters is still under development at this time. We hope to expand the current rule set in the expert system to support more rules.

An important issue when creating an urban model is to consider its use. If it is aimed at a realtime simulation one must consider optimisations, such as level of detail. We intend to add this to the current system by generating a number of different versions of the same model at differing levels of complexity. This can be supported directly by the system.

Another aspect of the system is that, since each model is generated from a set of parameters, there is a finite number of buildings that can be generated. Therefore, buildings can be created on the fly at any time, by just using the parameters and the 2D outline. This means a highly detailed house can, on average, be compressed into 20 bytes or less. If fewer parameters are used it can be even less, although the representation of the building will become less accurate. This type of compression is useful for large scale city/urban models since considerably less memory is required. Work is underway to investigate its uses within distributed virtual environments[9], where the compressed parametric form of the buildings leaves more bandwidth to be utilised by the important and interesting parts of the urban environment.

For historical simulations we intend to introduce an element of time. Each building or set of buildings would contain construction and destruction dates. Also, each of the parameters within the building could contain start and end dates, to allow for modifications to the building over its lifetime.

The creation of an urban primitive database and an urban architectural rule-based database would seem to be the way forward for large-scale urban modelling.

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