Low Tech Approach to 3D Urban Modeling

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Abstract. *Over the last decade various examples of urban 3D models have been created employing various techniques for data collection and model building. The problems faced are well documented, issues of accuracy, complexity and utility of the models has also been addressed. This paper presents a low tech approach to accurate city modeling focusing on engineering applications, browsing/experiencing applications as well as multi-layering time based analyses, historical info overlaying for use in interactive real time applications (museum exhibitions, research projects for behavioral patterns of users in 3D urban environments, marketing, tourism, etc). The pros and cons of the proposed methodology are analyzed and ways forward suggested.*
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Introduction

Over the last decade various examples of urban 3D models have been created employing different techniques for data collection and model building. Existing work was successfully summarized in a Round Table Session on "3D-City-Modeling" (eCAADe20, 2002) and in a collection of papers on the book "the Insights of Digital Cities" (Mao-Lin Chiu, ed, 2005). The problems faced are well documented, issues of accuracy, orientation and utility of the models has also been addressed. Latest advances are employing automated data collection and processing methods in order to create accurate, high bandwidth 3D models of cities. Contrary to the high-tech approaches to city modeling, this paper aims at developing a low cost approach to urban modeling utilizing existing knowledge, street based photography and site plans of the area.

The need for 3D urban models

It is important to analyze the cases/needs/uses of 3D urban scale digital models. Applications range from scientific and engineering to education and entertainment. Varying focus inevitably reflects on the platform, aim, budget, accuracy, detail, quality and bandwidth as demonstrated in the list below:

- Historical reconstructions
- Layering of urban information, services (underground – over ground)
- Radio signal propagation, optimization of aerial coverage
- Spatial Datasets mapped on actual properties/buildings/communal spaces/streets/parks, etc
- Planning proposal visualizations in sensitive areas
- Facility management
- Amenities/services/addresses/URLs etc
- Locative media experiments/applications
- Social networks

- Games
- Navigation
- Google maps/GPS driven applications

It must be stressed that not a single type of 3D digital model is suitable for all these applications. Level of accuracy may be low for some applications whereas detail must be high on others. Texturing on building facades may be necessary on some applications, whereas street furniture, textured streets and pavements, humans, cars etc may be advantageous or even necessary on others. Certain applications are response sensitive whereas others must be greatly optimized on size/bandwidth. Some are standalone suitable for terabytes of stored information whereas others are meant to run on mobile devices/cellular phones/GPS receivers/handheld computers where processing power and size is at premium. Finally level or realism attained maybe a vital ingredient of some applications and not at all considered in other.

Building a 3D urban model

In order to create a suitable digital model for each use, an appropriate method must be selected and employed. Latest advances are employing automated data collection and processing methods in order to create accurate, high bandwidth 3D models of cities (Lang, 2007 and others). Methods of acquiring urban scale 3D data digitally are still only few, namely:

- Aerial stereo photogrammetry
- 3D GIS pseudo model (based on recorded building properties, as number of storeys, typology of roof, etc)
- Laser scanning producing massive 3D point clouds
- Street level modeling using moving vehicles fitted with dedicated capture systems, differential GPSs, etc
- Street level photogrammetric techniques mixed with digital plans and other sources

Proposed Method

The paper presents a low tech, non-automated, accurate approach to urban modeling. The approach is based on street level photogrammetric methods employing the following steps:

Digital imaging of the area

Using a wide-angle lens equipped digital camera each building elevation must be included in at least two photographs from different (preferably opposing) viewing angles to enable texture perspective correction by the software employed. Wide angle lens is necessary in order to have few inclusive photographs to work with. There is no need to mark field of view direction and camera position nor is there a need for geo-referencing the photographs. A 5Mpixel resolution is sufficient; 8Mpixel is becoming unnecessary (as it is explained in the texturing section later on)

3D model building

Commercial software such as Photomodeler™ (or the equivalent Imagemodeler™) is employed to create accurately textured 3D models of each building. The process involves importing the relevant images, identifying common points (typically facade edges, balconies, balustrades, fences, openings, etc) and linking them along the different photographs using triangulated surface planes. "Resolving" the tagged photographs, builds the control points in 3D space, constructing the facade elements and resulting in a 3D model of the building with the appropriate texture information in bitmap files produced by the program. Typically this is stored in the format of 3ds MAXScript ™ in order to easily export the texture coordinates for the building geometry.

Following, the image files created are processed in PhotoShop™ or similar image editing software in order to remove artifacts that couldn't be avoided in the actual photographs (vehicles, street furniture, signs, trees, people walking, etc). The result is 3D textured models of each building per urban block. It should be noted that these models are not really in scale (there is hardly any reason to spend extra time on the 2D to 3D modeling software in order to get the scale "almost right") – it is easier to deal with this problem at a later step.

2D backdrop

Creating the 2D plan backdrop where all individual building models are placed is necessary before we can start putting together the whole model. Widely acceptable plans (if at all available) should be used in order to reduce disputes on dimensioning, borders etc when new projects are later on included on the existing model (general compatibility issues). In the UK the Ordnance Survey maps would be the best choice, in Greece the Military Geographic Services is the acknowledged provider albeit of (typically) low quality and rather old maps and/or aerial photographic pairs.

Assembling the urban model

The vector based referenced drawing produced in the previous step is imported in 3dsMax™ and organized in individual project files per urban block. This simplifies the process of working with complex geometry and keeps 3D geometry in small manageable parts linked together in order to create the final product. Inlining (to use a VRML term) is the preferred method of minimizing bandwidth usage as only the needed parts of the detailed geometry will be loaded from the server.

Building level modeling

One by one all individual buildings (based on the MAXScript format descriptions) are created. Each building is "placed" in its actual position using the 2D backdrop as a reference, via transformations, rotations, scaling and often small scale stretching. Each building is checked as far as geometric representation is concerned in terms of:

- Completeness, as typically a photo-to-3D model will be lacking the walls of the building not visible from the street where the photos are taken. In order to draw them, the digital plan is used as a reference. Very often fences, ground level layout detailing will be also missing and need to be modeled and included.
- Correctness, main problem being the verticality of the building components, as in walls, doors, windows. Roofing type and material is another area that needs clarification on each building, as street level photographic surveying is often unable to provide enough information. Google Earth™ is often the best way of cross checking material, color, type of roofing, especially if aerial photographs are too old for the area being modeled.
- Placement in the overall city model, as the whole process of scaling/stretching may alter the geometric properties of a building and its Z-elevation.

Each building is grouped in one entity leading to the creation of one node per building making it easier to identify each property (based on the street name and number), map information and link to external databases.

Levels of Detail (LOD)

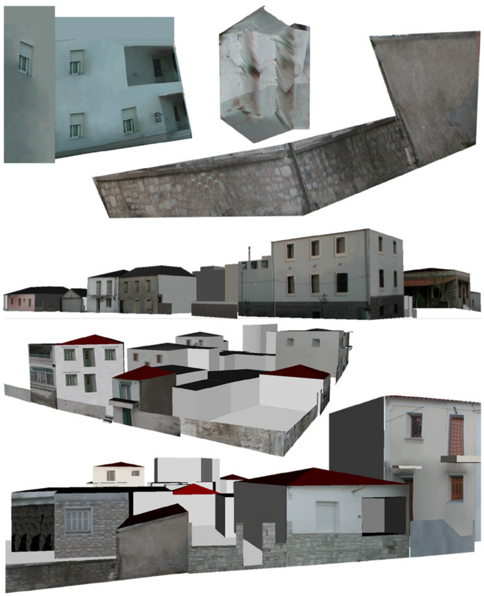
Unlike the methodology employed in my previous work (Bourdakis 1997), there are only two levels of detail necessary in this approach. The rationale is that the ever increasing complexity of the 4 LOD approach is extremely laborious as there is no way of automating such a process and only beneficial to purely engineering (mainly planning) applications.

- The low level includes all street, pavement, grass and generally landscape geometric description together with the low polygon count description of each urban block buildings – not exceeding typically 100faces per urban block. Depending on the topology and size of the urban block, the low polygon model may be one, or split into a series of simplified masses per street façade (in elongated building fronts, or special cases). No textures are included at this level.
- On the high level, the low polygon count descrip-

tion for the buildings is replaced by the actual textured geometry of each individual building together with any trees, street furniture, textures on streets, grass, etc.

Texturing

The edited/corrected bitmap files are rescaled and saved in medium quality JPEG files (Quality Value of around 30) with pixel sizes in the power of 2. Preferred values are 512X512 or 1024X1024pixels hence making high resolution photographs unnecessary. Not adhering to the original texture file proportions is not an issue since the texturing coordinate information is stored within the geometric description, hence the 3dsMAX geometry and eventually the VRML97 files making sure that the texture will unfold properly over the described geometry.



Interactive formats

The resulting model can be easily converted to VRML97 (the de facto standard for 3D interactive modeling in the WWW), X3D and other proprietary or open source real-time engines found in 3D games.

Discussion

The proposed method has advantages in terms of time spend creating the 3D model, quality of texturing as it's a semi-automated process within the photo-to-3Dmodeling software, accuracy and compatibility / adhering to existing 2D plans. There is enough scope for the designer / planner / modeler to interpret the environment in the best possible way, optimize, selectively focus on buildings / elements and eventually create a suitable model for the perceived application in a relatively short period of time. Furthermore, the lower geometric complexity and higher texturing information 3D models produced are less labor intensive in their creation without sacrificing navigability and rendering since texturing capabilities of the average 3D graphics hardware are currently greater than the particular needs.

This modeling approach is well suited, and thus can accurately depict, non-repetitive, random buildings widely found in urban settings developed over centuries, typical of European cities and especially true on Greek city centers. This technique does not rely on typological feature extraction from canonical structures, identical buildings, large scale developments and/or high rise office/housing buildings typical of "new" cities.

In the method described, approximately 20% of the effort needed is in the field work (photographic documentation), 40% on photo-to-3D conversion and the rest on the final 3D modeling/synthesis of the urban model. The overall labor involved in building an urban model using the methodology presented in this paper is notably shorter than the old purely geometry based approach used by the author in the London West End and Bath City models. It is estimated that there is a 30% reduction in time needed and this has to be considered together with the fact that the produced models are better suited to lay people due to the better visuals through extensive texturing.

Testing this modeling approach in the Ag. Varvara model (PICT project, Bourdakis and Chronaki, 2005) in a series of case studies with computer illiterate members of the public, it was noticed that the textured facades make for a much easier navigation in the 3D model. The ideal solution is a mix between geometry and texturing, utilizing some 'selective texturing technique' with textures focusing on elements that facilitate way finding and orienting oneself, but not creating a fake impression of a realistic model (which it is not and was not intended to be).

Future work

The digital model making process analyzed above has worked flawlessly over the past few months testing and building the old city of Volos in Greece, however a few issues came to light that need addressing:

- 'Building's geometric description qualities': namely the verticality and horizontality of the structural elements caused great problems and are extremely difficult to address manually. Verticality is addressed by parsing the MAXscript™ files through suitable filters that identify XY coordinates matching and edit them down to an accuracy of one millimeter (3 decimal points compared to the standard 5 digits). Horizontality is more complex as there are cases that sloping wall endings (mainly towards the ground) are acceptable (following a sloping ground/pavement). Hence, it was decided to do the Z coordinate corrections interactively via a custom made MAXscript™.
- 'Landscape modeling' is another issue that needs to be addressed, since one has to work manually and built 3D surfaces from spot heights and some information extracted out of topographic contours. There is no easy way of differentiating tarmac from pavement and the whole process is quite complicated. A script where spot heights are selected and pavement contours are set is under development.
- As a result, 'placing buildings on hilly landscapes' especially when detached is another difficult task. Building wall endings to the ground is a rather inaccurate way of addressing the issue, together with comparisons of the produced model to panoramic photographs of the street facades.
- A 'feature extraction algorithm' would be beneficial, where textures are processed in ways that only the strong/important elements are highlighted in an eclectic manner introducing a quality in the textures that is currently lacking. The perceived realism to a great extent an unwanted side effect of improving navigability without increasing the geometric complexity of the model must be also addressed. A custom filter focusing on structural elements/shadows in the photographs whilst "flattening" realistic details and smoothing colors would be the ideal solution into creating textures that are informative yet non-realistic.
- Finally, 'linking up the building nodes to databases' involves further developments in automating the VRML anchor nodes, or other type of query mechanisms to support it.

Conclusions

The proposed methodology proved successful in creating urban scale models with minimum resources in terms of maps, plans, aerial stereo photographic pairs, etc needed. Modeling complexity and skills are kept to a minimum and time resources are reduced compared to other manual techniques. The resulting models have varying degrees/possibilities of utilization in fields ranging from engineering to tourism, entertainment, commerce, public consultation, e-democracy exercises and database applications.

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