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Visualization Data Needs in Urban Environmental Planning and Design

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ABSTRACT

Photogrammetry has an important enabling role to play in making visualization technology practical and cost effective. This paper focuses on visualization techniques that satisfy the practical requirements of a series of urban environmental planning and design case studies done at the Centre for Landscape Research (CLR). It will illustrate some of the more important data characteristics that help to make visualization effective in practice. The paper will conclude with an outline of research topics that we would like to see the field of photogrammetry address. If these new tools can be made, we believe their introduction will accelerate the use of photo-textured visualization in planning and design practice

1. AN EVOLUTION OF PLANNING PRACTICE

Virtual reality and three-dimensional visualization are on the verge of changing the practice of urban environmental planning and design. Instead of presenting citizens with abstract maps and descriptive text to explain, analyze and debate design ideas and urban processes, planners will be able to show people explicit phototextured information of what their city will look like after a proposed change. This evolution in practice could meet with some skepticism from professionals who may feel they are well enough trained to “see” the implications of ideas in map and plan form. However, it is our experience that once clients and the public develop a taste for this form of communication they will demand that planning practice change.

Figure 1: Stanley Park, Toronto. A model optimized for studying the effects of infill housing.

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1.1. Visualization that Overcomes Differences in Spatial Literacy

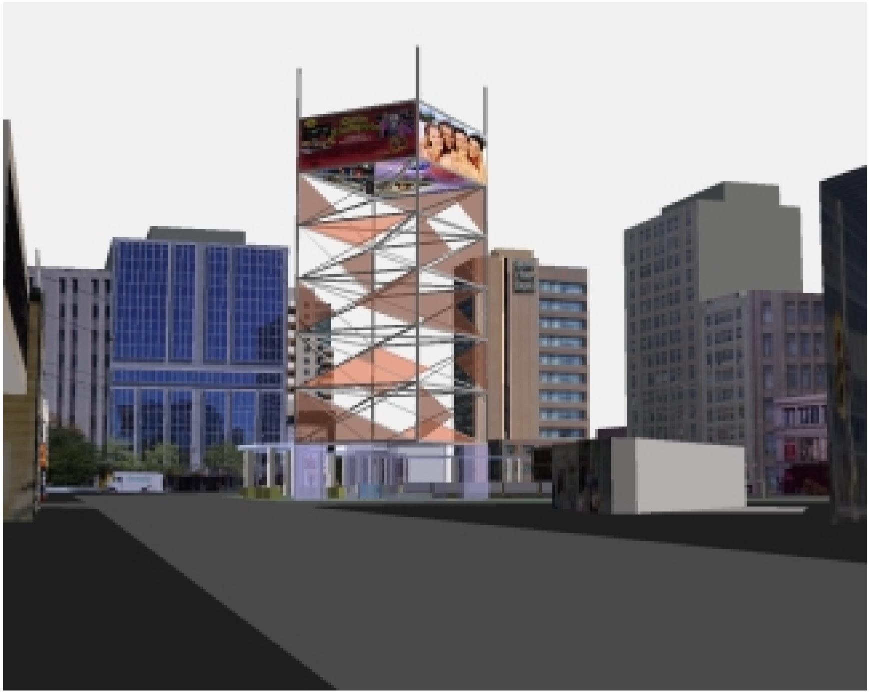

Figure 2: Student proposal for a media tower in Dundas Square, Toronto.

Phototextured three-dimensional models are easy for people to understand quickly. They can recognize specific elements and orient their view in terms of spatial position and scale. Unless people have had a lot of experience reading plans, the traditional products of planning and GIS can be undecipherable or confusing to non-experts. This can leave people with the wrong impression of a design's positive and negative aspects. Phototextured models serve as an excellent base to relate plan details and other information.

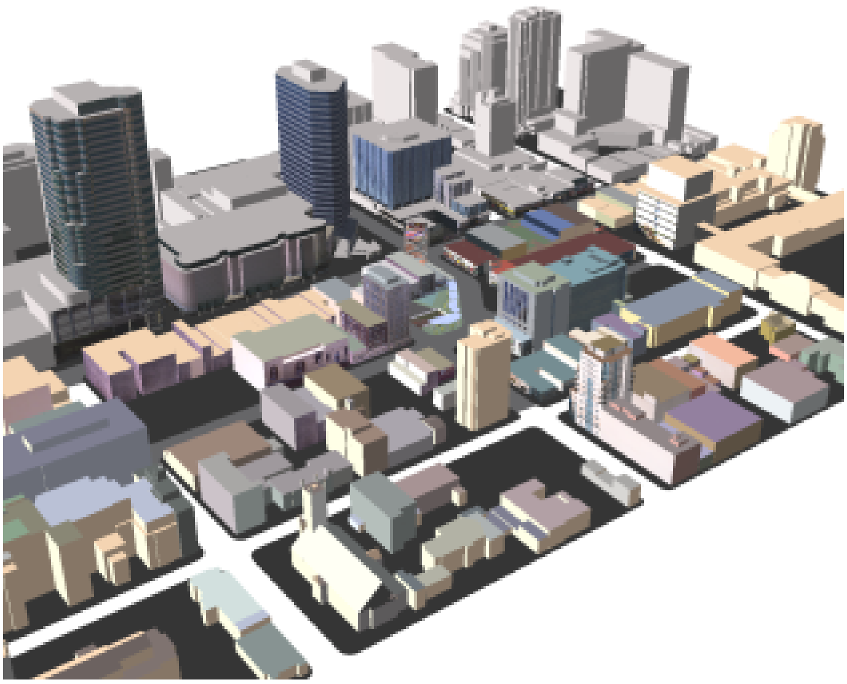

Figure 3: A portion of the geometric model made by the City of Toronto. Students applied terrestrial gathered textures to complete this hybrid design base model.

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It is relatively easy to layer abstract phenomena over a detailed model. The computational power of this media to transform and instantly compare alternative representations provides decision-makers with unprecedented flexibility. One can easily use an explicit model to spatially orient people. Then detail of an explicit model can then be suppressed to highlight a specific issue or factor. This allows one to show abstract information and systematically refer back to the explicit phototextured scene. The systematic comparable nature of digital visualization media provides the opportunity to overcome basic visual and spatial literacy differences between experts and clients.

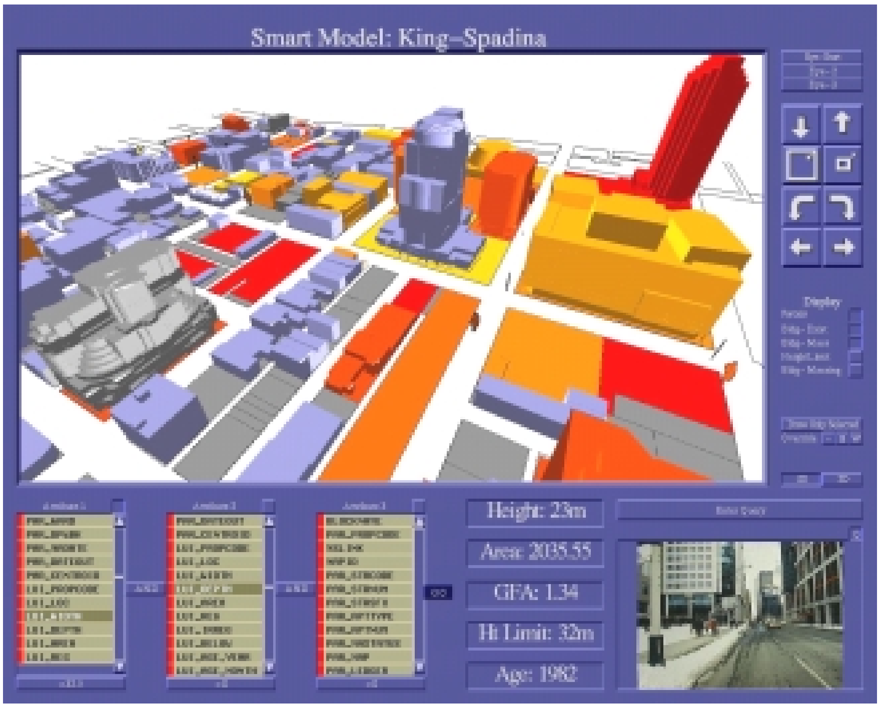

Figure 4: Polytrim used as an interactive 3D interface to abstract data in City of Toronto Database.

We expect that when visualization tools and good data are widely available, no one will be able to propose changes to a city without a dialogue that includes a systematic investigation of the visual implications of a design. Even more significant, the long-term implications of a policy that incrementally transforms the visual experience of a place will be possible to simulate, discuss and explicitly debate. Some trends in urban land use appear insignificant until the net effect of hundreds of small-scale actions by individual property owners is magnified over several years. The capacity to see into the future is tied to having a good quality base condition model. This is something that photogrammetric methods can do a great deal to provide.

1.2. 3D CAD City Models of the Past Ten Years Are Comparable to Today's Prototype Automated 3D Building Extraction Examples

The earliest examples came from consulting firms such as Skidmore Owens and Merrill (SOM). SOM's Chicago wire frame model of the early 1980s inspired much of the early work in this area. This private company used visualizations to impress clients and win project work. Their precedent continues with companies that do a lot of development work in a city. An example of this type of private database is a highly detailed geometric model of Melbourne we have used in conjunction with virtual design studio teaching with the University of Melbourne (Figure 5) This model was constructed using architectural drawings and field estimation. An even more detailed model created from surveyed information was made in the 1990's of the City of Bath, England by the CASA research group at the University of Bath. Similarly, a long tradition of building and visualizing city models has been going on by research units at UCLA and ABACUS at the University of Strathclyde. The City of Toronto's Urban Design Department is a good example of a municipal government with over a ten year history of incrementally assigning staff time to the assembly of a CAD model of extensive areas of the city for use in decision-making. All of these modeling exercises generated results comparable to that promised by recent advances in automatic photogrammetric building and terrain extraction.

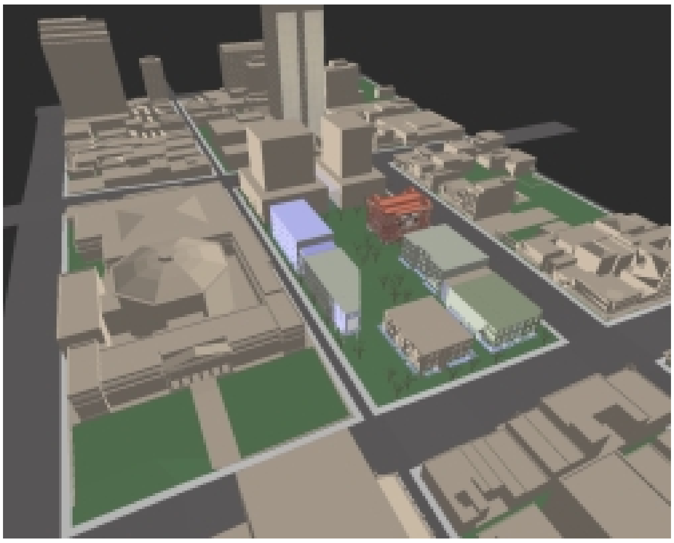

Figure 5: A portion of a detailed geometric base model of Melbourne, Australia used in a collaborative design studio exercise done via the internet with the University of Melbourne.

Figure 6: Example of a portion of an extremely, high detail geometric city model of Bath England created by CASA, University of Bath displayed in Polytrim – rendered with fuzzy line algorithm to mimic hand drawing.

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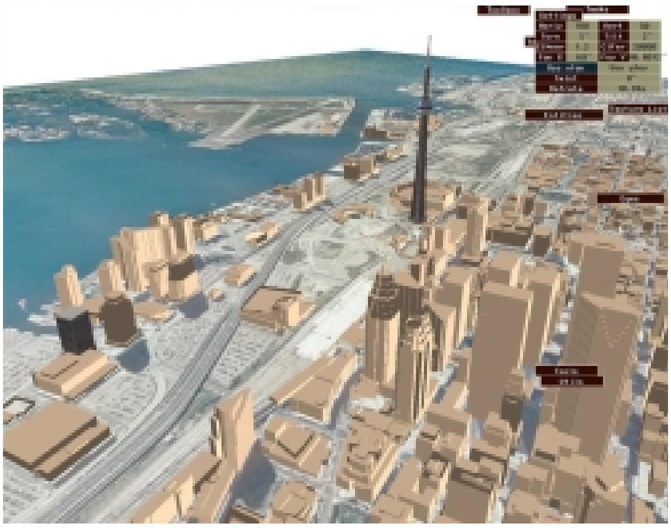

Figure 7: Geometric model created by the City of Toronto over orthophotos available over the network from the University of Toronto (UofT) digital library. These data are combined in Polytrim and are typical of what many students at Toronto now use as base models in CAD software. City urban design staff make extensive use of the model to test various planning and design proposals.

1.3. Available 3D Models Lead to More Testing of the Visual Experience of People

Many cities, universities and consulting firms have been constructing three-dimensional models of large sections of the urban landscape for more than a decade. We can see the beginnings of a change in planning in those cities where a three dimensional model of large areas has been in place for a few years. When a model is in place and available, we see more and more examples of design proposals tested in the context of a person's visual experience. It should be possible for citizens of a community to understand what development proposals or management strategies will look like. Traditional visualization is something that comes at the end of a process. The artist's impression of a design is usually used to sell ideas not seriously test the validity of ideas. Too often, detailed perspective images are made after the significant decisions about the design are complete. Technology has not yet challenged the politics and practices of professional to change significantly. To this point, two-dimensional GIS technology used in practice, has largely mimicked the conventions of plan and map making.

Generally, the cities that have made extensive use of three-dimensional models in planning and review of design proposals are the exception. A unique and extraordinary circumstance can usually be traced to the use of the technology (unique heritage, massive redevelopment or an innovative planner, politician or public interest group). Advanced visualization techniques are not a part of routine planning investigation. For instance, CLR's sustained involvement with the planning of Ottawa-Hull is because the cities comprise Canada's Capital. No other Canadian metropolitan region has a distinct agency overseeing the preservation a city's visual and urban design resources. In this respect, I believe that these techniques are more likely to be used on a sustained and routine basis in European cities. The lesson from our experience may be more useful abroad. The cultural value placed on historic continuity combined with the tremendous urban design resource of Medieval and Renaissance town cores may motivate European cities to use visualization on a day-to-day basis before most North American municipalities. The work we do in the City of Toronto is sustained because the CLR is based in the city and periodically city staff with innovative ideas turn to us for assistance. We have used these opportunities to gain experience and develop a variety of techniques and software.

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2. VISUALIZATION TOOLS ARE NO LONGER AN IMPEDIMENT

The tools to do these projects have matured. A steady increase in affordable software and equipment are coming on the market (this trend will accelerate in the next two years due to mass production of extremely advanced texture mapped graphics for PC video games). One no longer needs expensive research equipment and software to make effective use of urban visualization technology.

Our students now place virtual reality models on their World Wide Web home pages. Faculty and friends look at and "walk-through" the designs using PCs at home. This year's student projects are displaying as quickly on a PC using a free VRML plug-in viewer for a web browser as specialized graphics workstations could display models two or three years ago. We are now at the stage where the technical ability to use visualization is equal to that we used in our professional and research work during the past ten years. The same models are possible to visualize on the PCs sitting in the typical North American middle class home. Anyone with cable TV or a good phone line is in a position to use this technology "freely".

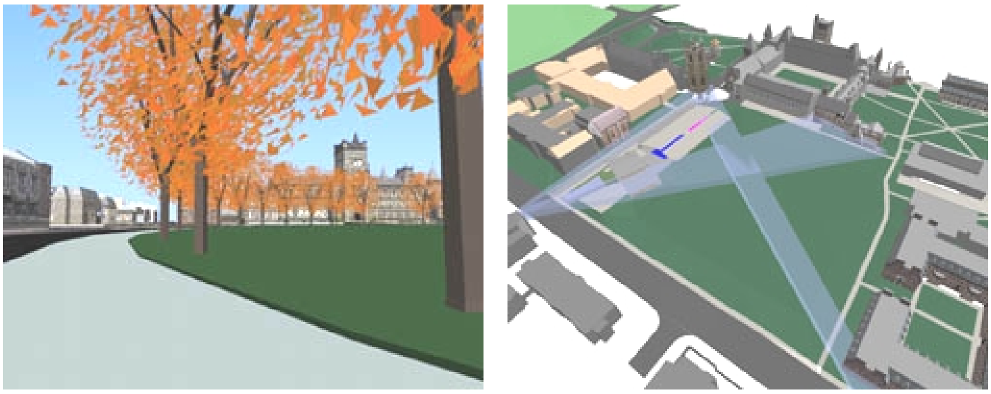

Figure 8: Examples of using a phototextured model for design study. Student VRML models. http://www.student.fald.utoronto.ca/~pjA95/COURSE_W/current_courses/VDS99/PROJECT3/walk/cawalk.html

Previous breakthroughs in visualization required one to have access to a professional workstation. This latest stage of development makes the average municipality capable of taking advantage of the World Wide Web to publish and communicate with members of its community. This is no small revolution in capability.

Given this fact, why aren't community planners actively using these techniques yet? There are significant cultural and political reasons that will lead some cities to be slow or reluctant to use the techniques outlined here in planning. Our experience suggests the reluctance will evaporate once clients or citizens begin to demand the use of the technology. For instance, computer aided design (CAD) was not widely adopted by small and medium sized architectural offices until they had no choice. There was a lag of between three to seven years between when it was technically and economically realistic to use CAD tools and the time that every student graduating from our school was required to have CAD skills to get a job interview. We expect a similar cultural lag in city planning with respect to visualization and practice.

3. DATABASE CREATION IS THE MOST SIGNIFICANT PROBLEM

The Centre for Landscape Research (CLR) has been building advanced visualization software and databases for experimentation in real-world planning and design applications for fifteen years. Our experience suggests that the greatest remaining technical obstacle to over come in the advancement

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of three-dimensional visualization techniques in planning is the creation of data. The most expensive part of doing a visualization is no longer the software and hardware. The most significant cost is the creation of a good quality flexible database.

3.1. Automatic Data Base Generation

CLR identified this problem in its consulting at the beginning of the 1990's (Danahy 95). Our real-time interactive visualization and decision support tools had reached the stage where we could test urban design ideas in minutes. Images were four times higher in resolution and took seconds to draw compared to the measure of minutes and hours used five years earlier in the mid 1980's. Our work reached the stage where an afternoon workshop could generate more analytical work than three months of visualization consulting had been able to accomplish two or three years prior to that project. However, we could only respond to issues that arose in areas of the city where we had already prepared a database. The laborious process of hand digitizing and interactively crafting each geometric model of buildings and terrain was and still is much too time consuming for planning budgets.

Commercially available GIS was maturing at the start of the 1990's. The municipalities we were dealing with could provide us with accurate two dimensional digital vector mapping (derived from airphotos) that included elevation data for contours and spot elevations. We wrote a series of filters that made it possible for us to automatically assemble polygonal terrain models. These models were

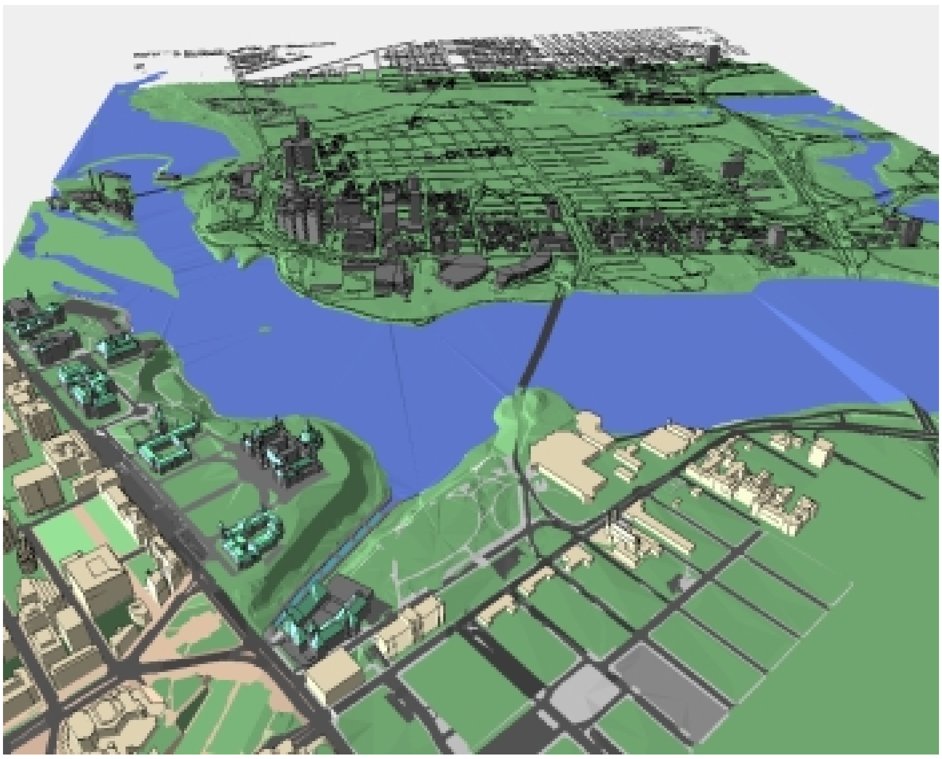

Figure 9: Ottawa-Hull Model created from GIS data.

composed of distinct polygonal surface areas for roads, sidewalks, parking, and other vegetated areas such as lawns or slopes. Where aerial photography of rooftops had been mapped, we were also able to semi automate the modeling of building massing. If explicit elevations for rooftops were not available, we assigned attributes for the number of floors in buildings and extruded these structures by an average floor-to-floor height to get approximate massing of contextual residential areas surrounding the downtown.

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The techniques were so powerful that we put the database modeling part of our consulting at CLR out of business. Costs ranged between 2 and 5 days to prepare a geometric data model of building masses for subsequent urban design studies. This activity used to take up to three months and cost tens of thousands of dollars. Since our model building was automated, the more the client invested in detailed digital data before starting the project, the greater the accuracy and detail we could provide in the three dimensional model for the same project set up fee (Danahy 97)

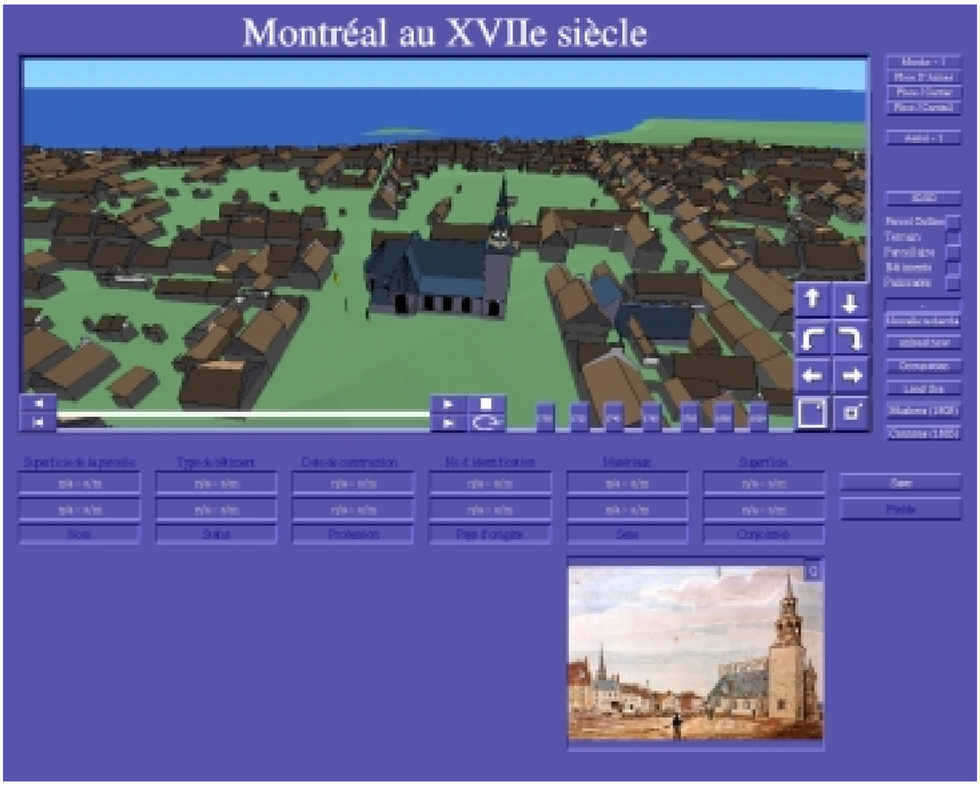

Figure 10: Parametric timeline (typological) model of old Montreal automatically constructed from database records. Signature buildings such as the church are explicit reconstructions from plans.

In 1991 for a subsequent research project and exhibition for the Canadian Centre for Architecture (CCA), we extended these techniques to reconstruct a virtual model of the evolution of the old city of Montreal. The interactive continuos time-line model covered the period involving the transition between French and English control (1700-1800) of the city (Figure 10). Each land record transaction for the city was available from a research archive laboriously collected over twenty years and archived by the CCA in an Oracle database. Rodney Hoinkes of CLR, developed a system to link the database directly to CLR's research test bed (Polytrim). Polytrim filtered inputs from the database originating from real-time user inquiries. It attached parametric representations of archetypal buildings to the time-line slider control. The virtual city was built in real-time as one moved around the model and selected various parameters of urban development to study.
This prototype system was far ahead of its time as a precedent for planning practice because it will take considerable time before the GIS systems of cities capture enough data to be useful. The Montreal project illustrates the power of automated modeling tools linked to a well-defined parametric city model. The automatic parametric construction techniques used in this case hold little promise of providing explicit representations. This means that the Montreal model cannot present more than a typological representation of the city and its eye-level experience. If aerial photos were available in an archive, the process of creating the detailed models of signature buildings and gardens could have been constructed much more accurately and quickly. Instead, we used historic

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maps and paintings to create building models. In conclusion, this case study supports the idea that photogrammetric methods gain greater exclusive value, as greater explicit detail is required.

3.2. Phototextured Database Creation

A second generation of technological development in real-time visualization systems took place in the 1990's. This breakthrough in rendering is about to become readily available on personal computers. The ability to attach digital images to the polygon surfaces of real-time models with no decrease in the speed of rendering has a profound improvement in the quality of visualizations.

The cost of this capability can add a new time consuming dimension to the process of crafting a texture mapped virtual reality model. It now becomes necessary to gather explicit textures of building facades, vegetation and other elements of the urban landscape. A single repeatable typological texture of building types will not work in most cities. We find that after people get used to the technique they begin to look very closely at the textures and expect to see textures of specific trees and buildings.

Typological representations seldom adequately capture the eye-level experience a person would see on a given city street. The photo-realism of this technique draws people's attention to simplifications and inaccuracies. With time heuristics for combining multiple media in virtual models will develop. In the meantime, the default requirement in professional planning is to use phototextures carefully and accurately. An excellent example of the scale of this data base problem is outlined in the paper, Managing large 3D Urban Database Contents supporting Phototexture and Levels of Detail by Gruber 97.

The costs of manually creating these models are outlined in an interview of Bill Jepson on the process of creating UCLA's Virtual Los Angeles model (see UCLA URL links). Jepson outlines the costs of creating their models to be approximately 30 to 40 hours per city block (using students, this works out to $3,000 per block). It should be noted that Los Angeles buildings usually have flat roofs. These figures correlate very closely with CLR's experience creating a 20 block model of the downtown campus of the University of Toronto. It should be noted that the criteria for all of these precedent case studies was to make a model of high enough explicit detail that a person could "virtually" walk up to the door of a building. Both the Virtual Los Angeles model and the University of Toronto model do not include high detail of the ground surface in front of the viewer throughout the models. That aspect of explicit detail is lagging in development. Most solutions to this problem involve creating a high detail CAD model with archetypal material textures applied.

3.3. Data Base Abstraction Requirements

Our first requirement of a database is that it include the three primary types of urban landscape (terrain, vegetation, and built form). Second, within each of these types it is necessary to support at least three levels of abstraction in two basic ways. If this can be done, visualization techniques can be both effective and efficient (Danahy 97).

Three-dimensional visualization requires that each element have a geometric depiction (such as a polygon, see Figures 9, 10). The second important property this technology supports is the association of textural properties on the geometric surface (Figure 12). In a case where photogrammetric techniques are used to derive the geometric descriptions, the original image data can be textured onto the surfaces or data points (in the case of meshed terrain data). Each of these ways of depiction (geometric and image) can in turn have a symbolic, a typological, and an explicitly detailed level of abstraction. The key to making projects work lies in the development of an abstraction strategy that properly represents the primary elements of the urban landscape being studied. The approach described above forms a three by three matrix of representation possibilities (Figure 13).

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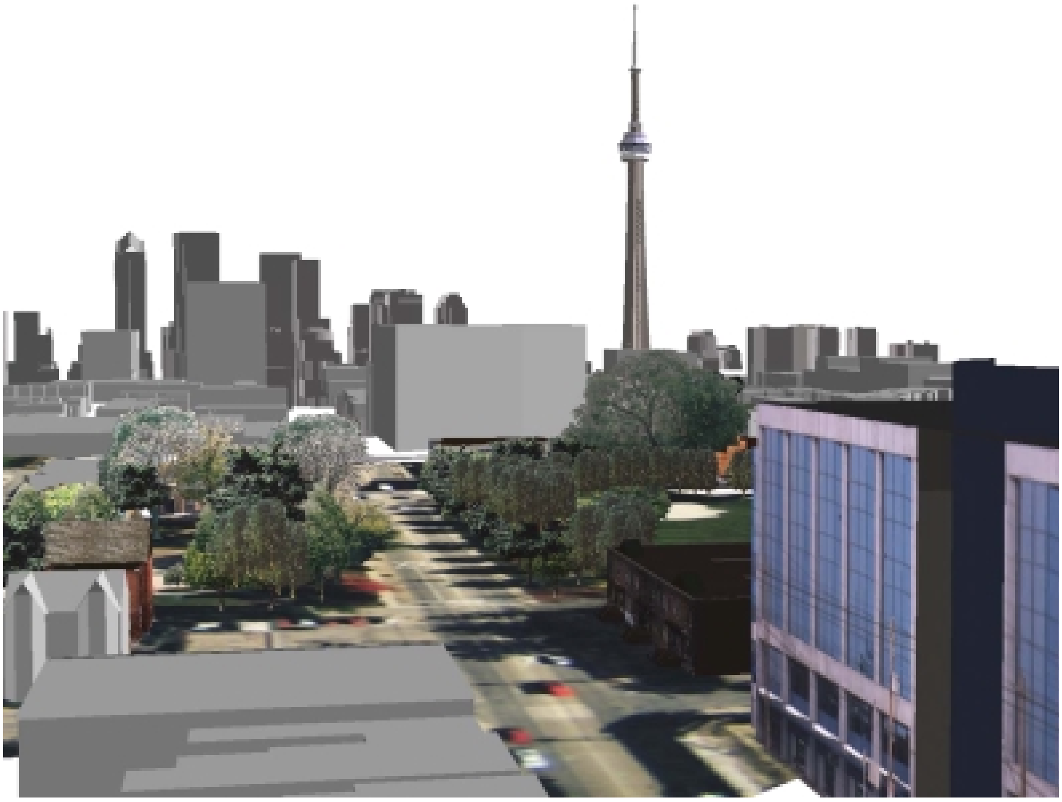

Figure 12: Stanley Park model with explicit textures of individual trees and buildings.

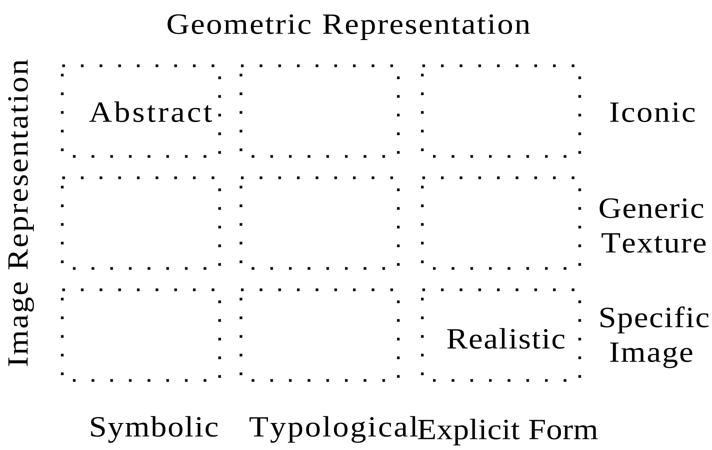

Figure 13: A representation abstraction matrix

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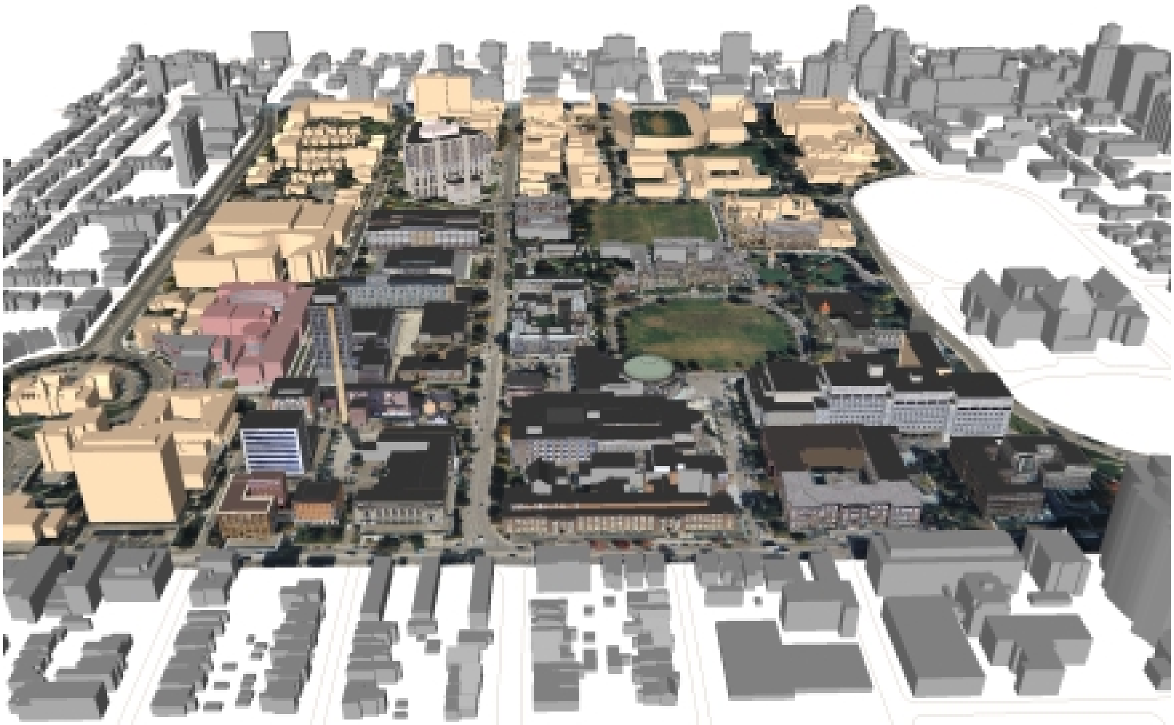

Figure 13: A phototexture model of the UofT campus set in a geometric context model of Toronto

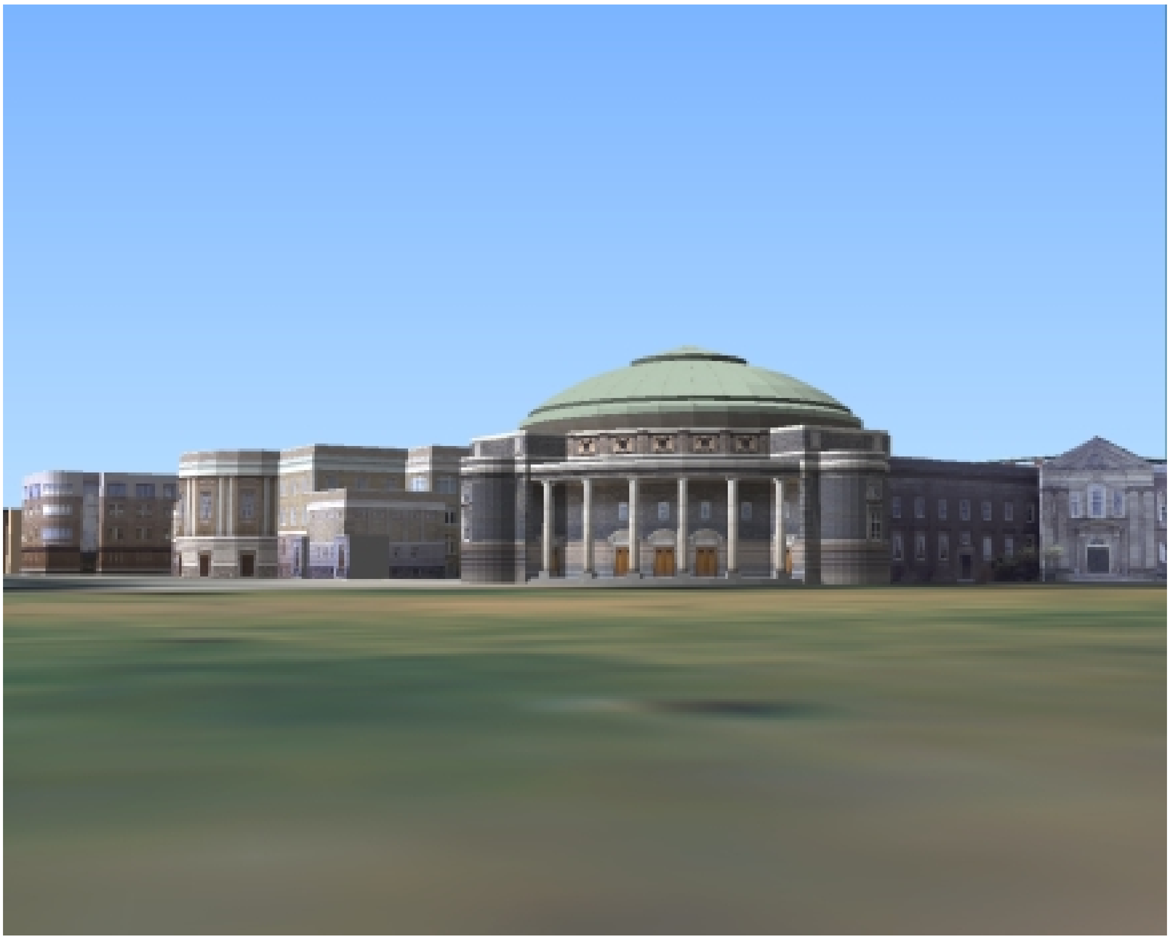

Figure 14: An unreal scene of the UofT campus devoid of urban furnishings, vegetation and people.

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Figure 15: Elements essential to foreground eye-level viewing; steps, walkways, fences, and trees.

3.4. The Influence on Data Modeling of View Position

Visualizations should be classified in terms of the viewing position relative to a model. We use three basic classifications to help evaluate and structure each landscape visualization problem;

1. aerial camera views: higher than 200m., provide strategic overviews (Figures 9, 13)
2. elevated oblique camera views: 200m. to 2m., allow the study of spatial arrangements (Figures 12, 16)
3. eye-level experience:1.8m. to1m. (tall adults to children or seated views), tests the visual sensory experience of people that will use a space. (Figures 14,15)

Efficient techniques such as “bill-boarded” texture mapped rectangular polygons of trees work well at low angles to the terrain. The same technique looks unrealistic if the camera is positioned higher. Steep viewing conditions require more ingenuity and visualization complexity to display artifacts such as trees. Conversely, draped aerial photos on relatively simple geometric models of terrain can adequately represent vegetative cover if viewed at a steep angle (i.e. above 45 degrees).

These distinctions in camera or eye position have a significant bearing on the structure of a scene and the model used to render the scene. The tradition in perspectival architectural rendering is to select a viewpoint 3 to 5 meters in the air. This larger-than-life view of a scene makes it much easier to illustrate spatial arrangements of the design. In addition, it avoids the requirement for ground plane detail in the area closest to the eye. This area on the ground in a perspective image can be extremely hard to draw well. In addition, it is often more visually dominant on a picture plane than the building being portrayed (hence, an additional ego based motivation to raise the camera position). The problem of portraying the ground plane information closest to the eye in walk-through visualizations is equally challenging to model and draw efficiently in computer visualization.

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4. CONCLUSION: CONTRIBUTION OF PHOTOGRAMMETRIC METHODS

This section will use the three classes of viewing position outlined above to organize an analysis of the contribution photogrammetric methods can make to the problem of building virtual city models. City models are being built with a combination of top-down (aerial photographic data) and bottom-up (terrestrial photographic data) methods of data gathering. It is going to take a combination of aerial and terrestrial photography with specialized adaptations of photogrammetric methods to cost effectively build high quality explicit models of cities that can be used for all three types of viewing.

4.1. Overview Strategic Visualization

Aerial photogrammetric methods are ideally suited for building models suitable for strategic overviews. Planning needs aerial strategic views with a combination of geometry and phototexturing. Phototextures help to orient people and provide an adequate sense of scale for illustrating concepts that have traditionally been shown as abstract plans. Information such as housing condition, density and census information can be shown as a theme over one of these models. Current research into automated building and terrain extraction will eventually produce models that can be directly used for this type of application. Future work focus on extracting geometric and texture representations of urban forest conditions.

4.2. Close-Range Oblique Visualization

Close-range oblique viewing conditions require a model that is made of both aerial and terrestrially derived geometry and texture. Visualizations that anticipate using this viewing condition can relax extreme detail but require data from both terrestrial and aerial photogrammetric methods.

4.3. Eye-Level Visualization

Eye-level viewing required to test what a design or policy will look like to people is primarily dependent on explicit representations of vertical surfaces. Aerial photogrammetry can be very useful in providing simple representations of wall surfaces by extruding building footprints to a relatively accurate elevation. This will help improve the accuracy of the base models used to begin crafting site models. Terrestrial images of walls can then be added as required by planning technicians to provide a readable visualization. If a highly accurate or realistic model is required, one needs to develop a geometric model of the vertical surfaces of buildings and trees. Terrestrial photogrammetry is an ideal means of capturing this level of detail. The greatest problem with current commercial terrestrial photogrammetric tools is the requirement to interactively mark every geometric point in every photograph. Models take as much time to prepare as hand field measurement.

Figure 16: This class two oblique view shows an optimum combination of geometric and phototexture detail (terrain, built form and vegetation). The image shows terrain geometry. Figure 1 shows this model with a phototexture airphoto and geometric trees. The surrounding context is modeled more simply using automatic techniques (from databases and 2D GIS data). Automatic building extraction from air photos should significantly reduce the costs of creating context models and the roof geometry. If close range terrestrial photogrammetric technology can be automated, the detail needed for class two oblique and class three eye level viewing should become viable to use on all planning and design projects.

4.4. Conclusion

Before visualization can transform planning and design practice, we require better quality base data. Current techniques for model creation are extremely time consuming. When one person can create detailed site specific models in a week, we will see a routine use of detailed visualization of proposals set in good quality context models. Automated (and semi automated) techniques for the extraction of roofs, terrain surfaces such as pavement and major tree

5. ACKNOWLEDGMENTS

The work illustrated in this paper is the result of contributions by many people. I would like to highlight the superb craftsmanship of Stephen Bohus, Russell Loveridge, Stephen King and the students in 5th yr Landscape Architecture, and the students from the past two years in my joint architecture and landscape architecture option studios, exhibited in CLR's latest models. And as always at CLR, Stephen Bohus and Rodney Hoinkes have made the work possible by continuously adding functionality to Polytrim. Professor Armin Gruen and Dr. Andre Streilein of the Swiss Federal Institute of Technology have been particularly helpful in assisting us to integrate their photo rectification routines into Polytrim. In addition, I would like to thank the staff at the City of

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Toronto, the National Capital Commission and the Canadian Centre for Architecture for their assistance in providing us with excellent base data to develop these studies.

6. WORLD WIDE WEB LINKS AND RESOURCES

Centre for Landscape Research, Faculty of Architecture, Landscape and Design,
University of Toronto
http://www.clr.utoronto.ca/

Chair of Photogrammetry and Remote Sensing, Institute of Geodesy and Photogrammetry
Swiss Federal Institute of Technology, Zurich
http://www.geod.ethz.ch/p02/projects/3DGIS/3DGIS.html

Centre for Advanced Studies in Architecture, University of Bath
http://www.bath.ac.uk/Centres/CASA/

South Devon, UK, was created using PhotoModeler by John Lee of Newcastle University
http://photomodeler.com/PROJS/VRMLTOWN/town.htm

Urban Simulation Laboratory, Department of Architecture and Urban Design, University of California at Los Angeles
http://www.gsaup.ucla.edu/bill/uSim.html

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