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VIRTUAL URBAN MODELING USING GIS

Abstract: This paper discusses various issues in urban modeling with focus on building visualization. Different existing geographic data, including DEM, DOQ, DRG and vector street maps, are collected, registered and geo-referenced into a common frame using a GIS. To ensure the high fidelity of the urban modeling, large-scale aerial photographs are also integrated through geo-rectification and mosaic. Detailed urban features such as green lands, parking lots, recreation places, roads as well as buildings are delineated within the GIS as a high resolution supplement to the above existing data. The ground elevation and buildings are merged to an integrated TIN structure over which texture images from the aerial photographs are draped so that a photorealistic view is achieved. The generated view can be queried via the database and browsed via the Internet.

INTRODUCTION

Urban planning and many other civil and social activities need a realistic visualization to assist their decision making process [Batty, et al, 1998]. Geographic data collection and realistic modeling are a primary prerequisite for the generation of effective visualization presentations. GIS (Geographic Information System) provides an effective tool to fulfill this task [Sugihara, 2000]. Common available geographic data include digital elevation model (DEM) at various spatial resolutions, digital ortho quard (DOQ), digital raster graphics (DRQ), and many other vector form thematic data, such as street, water and topography. However, for large scale (small area) urban applications, more detailed data are needed, which include detailed road maps, grass lands, parking lots, and most often buildings. All these need to be integrated into a GIS, properly modeled, displayed and queried in a three-dimensional environment.

This paper discusses the integration of various geographic data and modeling of detailed urban geographic features, especially buildings for the purpose of photorealistic visualization. Commonly available geographic data are imported into a GIS, registered and geo-referenced using the powerful GIS tools. In order to achieve a detailed urban modeling, large scale aerial photographs are geo-rectified and mosaicked. Detailed urban features such as grass lands, parking lots, recreation places, roads as well as buildings are delineated based on thus corrected aerial images. Building precision and topology are maintained to its best accuracy during its collection process. For photorealistic visualization, an integrated triangular network (TIN) is created by merging the DEM data with the 3-D building model which is obtained by extruding building boundaries according to its number of floors. Image textures from the aerial photos are then draped over this integrated TIN model so that a photorealistic view is created. The remainder of this paper first summarizes the commonly available data and its integration. After that the delineation of detailed urban features, especially buildings are discussed. The following section presents photorealistic views for the Purdue campus area. Concluding remarks are given at the end to summarize the gained experience and prospect the future research efforts.

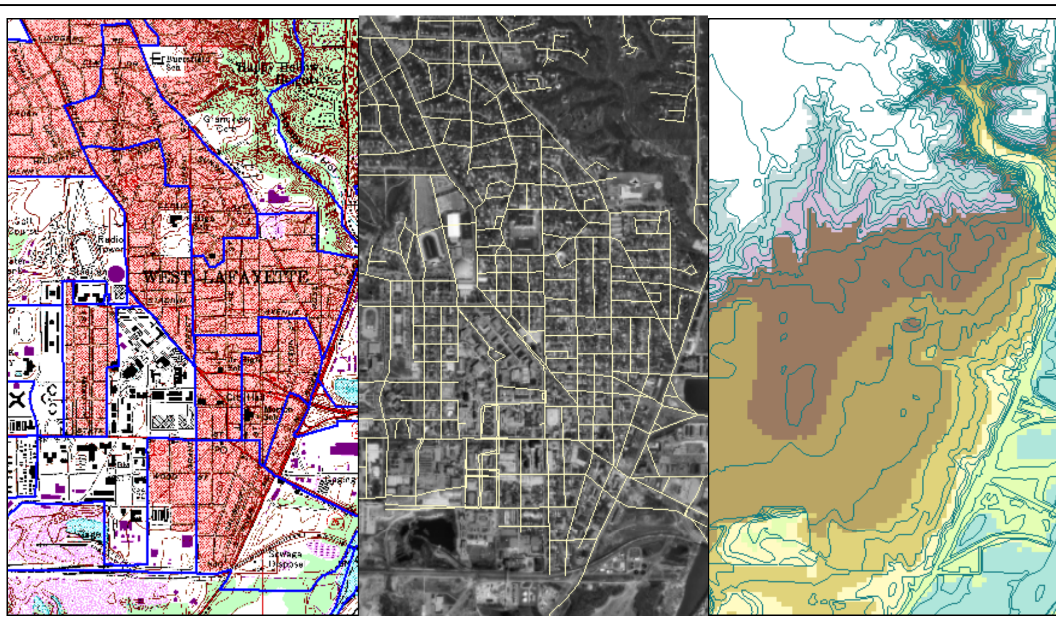
DATA INTEGRATION

Geographic data are often collected from different sources for various applications. They may have different formats, resolutions, references, accuracy, scales and levels of details. Available common geographic data for the city West Lafayette, Indiana are collected for the urban modeling purpose, including digital elevation model (DEM), scanned topographic map (DRG, digital raster graphics) at the scale 1:24,000, ortho images (DOQ, digital ortho quard) at spatial resolution 1 meter), aerial photographs and various vector data such as TIGER and GDT street maps. Table 1 summarizes the properties of those data sets. In order to create an urban model, the collected data need to be registered and referenced to a common frame. Geographical information system (GIS) provides powerful and convenient tools to perform this data integration task. ESRI's GIS products ArcView and ArcInfo are used to carry out this task. All the data are projected into UTM projection with the datum NAD 83. Figure 1 shows the results of vector data overlaid over the raster data.

The consistence of various geographic data is important for a good virtual modeling. Disparities among different data sets are found after registration and geo-reference. It is noticed most mis-registration is local and there is no systematic pattern found, except some noticeable offsets between streets and the DOQ images are observed. Comparing with other data sources, we infer that this mis-registration is due to the local quality of the DOQ data, which may not be rigorously rectified at some places.

Table 1. Data attributes

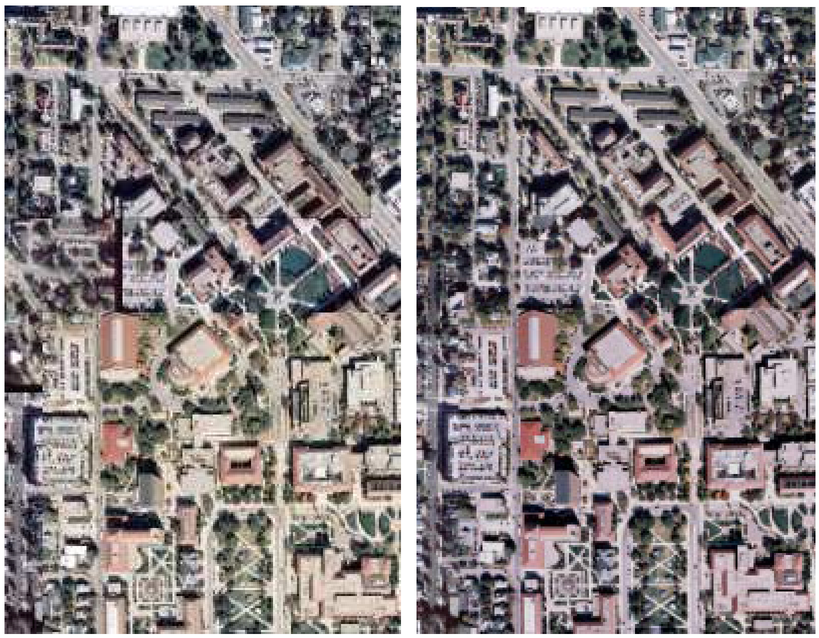
Data	Type	Cell Size (Ground Sample Distance)	Scale	Projection	Datum	Format
DRG 7.5 min	Raster	2.4384m	1:24k	UTM	NAD27	TIFF 6.0 w/ GeoTIFF tags
DOQ 3.75 min	Raster	1 x 1m	1:24k	UTM	NAD83	Mr.SID
DEM 1 deg	Raster	3" x 3"	1:250k	None - Geographic (Units = Decimal Seconds)	WGS84	USGS DEM
DEM 7.5 min	Raster	30 x 30m	N/A	UTM	NAD83	ESRI GRID
DLG (Hypso-graphy)	Vector	N/A	1:24k	UTM	NAD27	SDTS
TIGER themes	Vector	N/A	N/A	None - Geographic (Units = Decimal Degrees)	NAD27	ESRI Shapefile
Other (GDT street)	Vector	N/A	N/A	None - Geographic (Units = Decimal Degrees)	NAD27	ESRI Shapefile
Aerial photos	Raster	30µm	1:3600	N/A	N/A	TIFF 6.0



a. Census tracts and DRG b. Streets and DOQ c. DLG and 7.5min DEM

Figure 1. Integrated geographic data (West Lafayette, IN)

An urban model needs to have different levels of details. Current widely or even freely available geographic data cannot meet the requirements of high resolution application. Extra data are still needed. We have integrated large-scale aerial photographs over the Purdue campus area for this study. In order to create a seamless virtual model, the images need to be geo-rectified and mosaicked. For this purpose, the gray levels and the colors of the individual images are adjusted. Figure 2 presents a portion of the rectified and mosaicked results.



a. before mosaic b. after mosaic

Figure 2. Image mosaic (Purdue)

URBAN FEATURE COLLECTION

Detailed urban features are not available from existing data that are integrated into the GIS as described above. These features include, among others, new roads, grass lands, parking blocks, recreation places, buildings and others. Many literatures have discussed automatic solutions to this demand, however, most of them are still under development as research interests [Forstner,1999]. As an intermediate, yet practical and effective solution, GIS and image vendors are providing useful tools to manually collect 3-D GIS data [Stojic, 2000]. Recent utilization of existing GIS packages may provide reasonably good urban models, however, it is only limited to certain types of data sources, such as lidar elevation data [Trent and Shan, 2001]. In this study, the detailed urban features, including roads, parking places, open lands and buildings, are manually delineated based on the aerial images within the GIS.

A sample area with delineated features is shown in Figure 3. The green polygons show the digitized lawn and park areas, the red lines show the digitized streets, the gray polygons show the digitized parking lots, the yellow polygons show the digitized recreation areas and the blue polygons show the digitized buildings. For streets, their central lines are traced. Road intersections are treated as common nodes so that the road topology is kept in the digitization. This will benefit the application of the network analysis. A comparison of the original image and the digitized terrain features are seen in Figure 4.

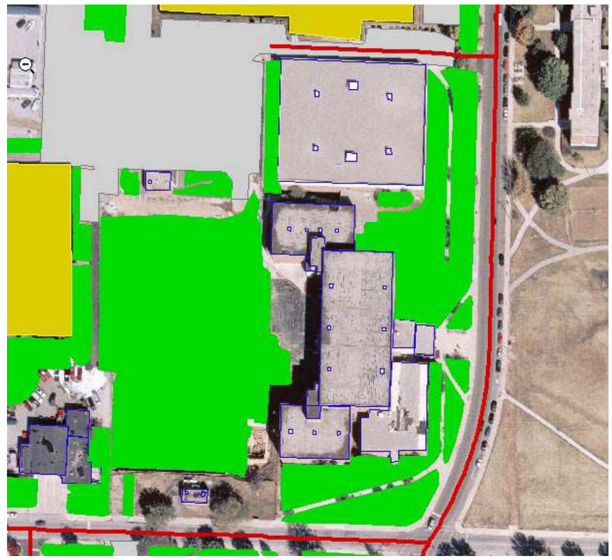


Figure 3. Delineated features

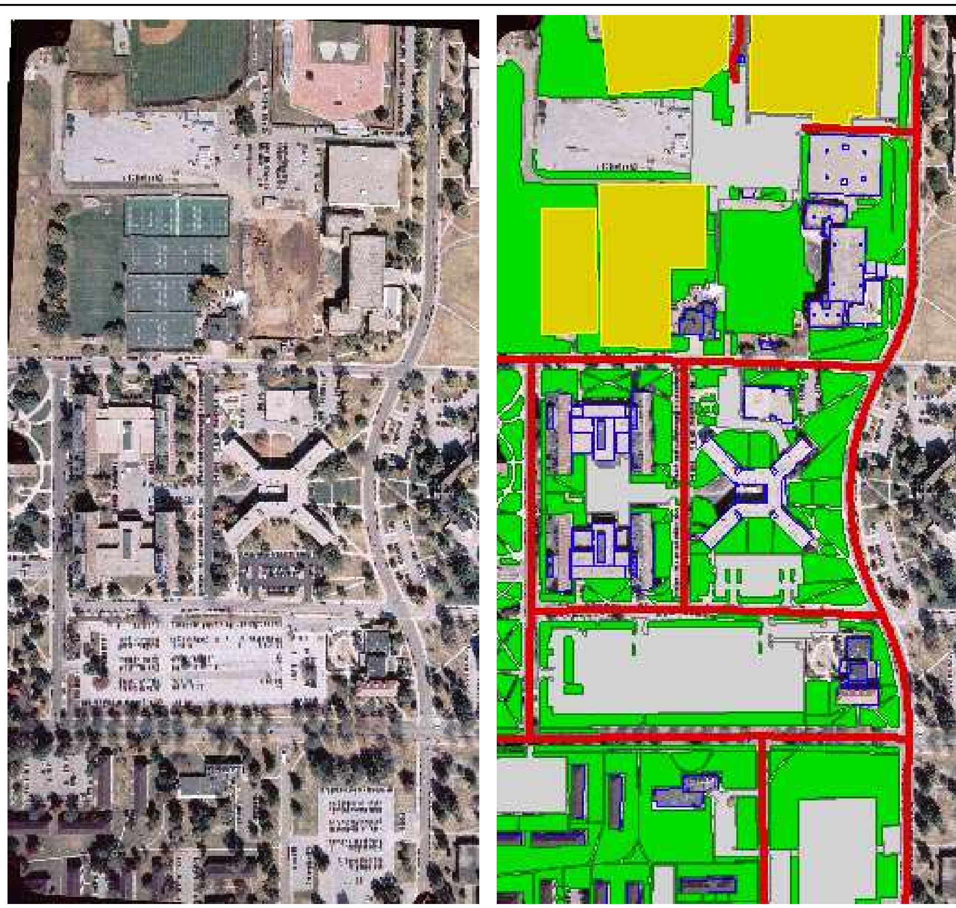
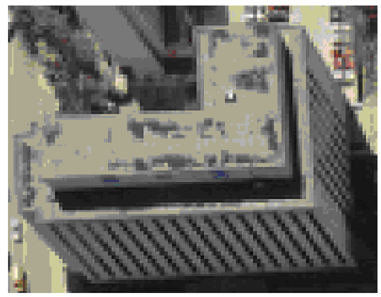


Figure 4. Image and its delineated features

The delineation of buildings exposes a major technical difficult in the urban modeling process, especially when using the large-scale aerial photographs. First, due to the shadow and relief displacement, only the building roof can be traced. This causes the buildings shift from their geometrically correct locations. Buildings at the boarder of the image have larger relief effect as opposed to the ones at the central part of the image. In either case, only the building roofs can be traced and no complete texture images for the building facades can be used. Figure 5 shows two building samples, one at the center and one at the boarder of the aerial photo.

a. at image center



b. at image boarder

Figure 5. Relief displacement of buildings

Another difficulty in building delineation is to handle the complexity of the building shape and its topology. Common boarders of buildings or portions of one building have to be identified and enforced by snapping the common edges and intersection nodes. Although incorrectness of topology or misalignment of common edges or nodes may not be noticeable in the wire-frame visualization results, they will be distinct when image textures from the aerial image are draped over the building roofs and even facades. Hence, precision delineation and correct topology for complex buildings are critical for a photo-realistic visualization.

Since only single photo is used, the third dimension of buildings can only be simplified, namely roofs are assumed to be flat. We estimate the number of floors of each building and use it as an attribute value of the buildings. The building's three-dimensional shape is obtained by extruding its delineated boundary according the number of floors. Figure 6 is a 3-D color-coded view of the delineated urban features.

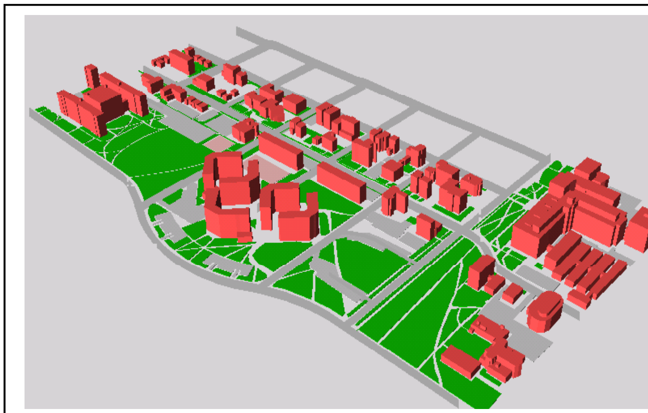
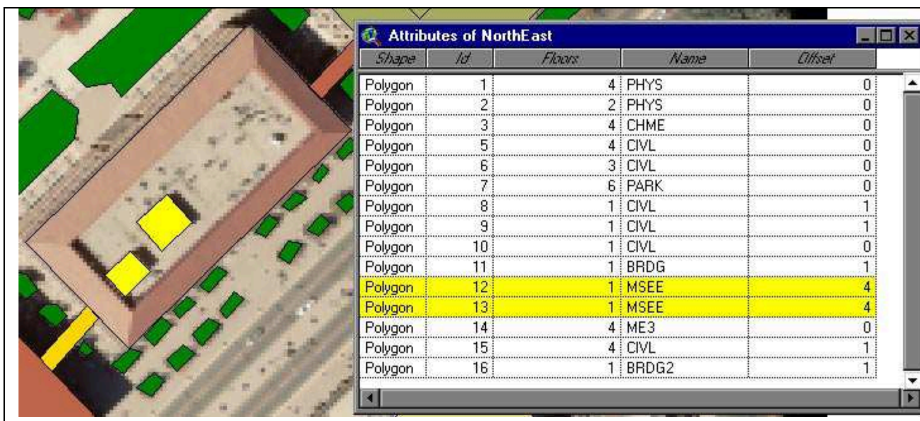


Figure 6. A color coded 3-D view of portion Purdue buildings (red), lawns (green), parking lots (gray), tennis courts (pink), streets (light gray).

In addition to geometric locations, feature thematic attributes need also to be input into the GIS. Most thematic attributes can be identified by interpreting the aerial photographs and using the existing Purdue campus map. As building heights are maintained as one of the attributes, small attachments on a building's main body as shown in yellow in Figure 7 have to be treated separately so that they can be queried as well as displayed correctly. For this purpose, we use two attributes to describe the building height, one is the number of floors of the main building body, the other is specific for the attachment to indicate its height offset above the main building. In this way, the database query will return complete and correct results.



Shape	Id	Floors	Name	Offset
Polygon	1	4	PHYS	0
Polygon	2	2	PHYS	0
Polygon	3	4	CHME	0
Polygon	5	4	CIVL	0
Polygon	6	3	CIVL	0
Polygon	7	6	PARK	0
Polygon	8	1	CIVL	1
Polygon	9	1	CIVL	1
Polygon	10	1	CIVL	0
Polygon	11	1	BRDG	1
Polygon	12	1	MSEE	4
Polygon	13	1	MSEE	4
Polygon	14	4	ME3	0
Polygon	15	4	CIVL	1
Polygon	16	1	BRDG2	1

Figure 7. Building main body and its attachments

PHOTOREALISTIC VIEW

This is to drape the aerial image or other images over the ground as well as buildings. In order to do so, the DEM is first converted to a triangulated irregular network (TIN), which is then merged with the extruded 3-D buildings. The aerial image is draped over the integrated TIN data so that a photo-realistic view is created. As is shown in Figure 8, most buildings are shown in their right shape. Roof images are well draped over the building models with detailed textures of high fidelity. As discussed earlier, the facade texture exposes a big uncertainty and different textures might be displayed at different locations of the same buildings. Buildings with the same textures may also look differently in the view. This problem cannot be fully resolved without using image textures obtained from ground photography and associating them with each facade in the building model process. In addition, misalignment between building boundaries and its image, the topologic inconsistence for complex buildings and building groups, may also cause an unrealistic local view of some building roofs. Using more accurate and realistic building models, such as slope roofs composed with computer assisted design (CAD) tools with certain 3-D GIS functions, will avoid this problem to a large extent. This demands an effective interaction between CAD and GIS tools.

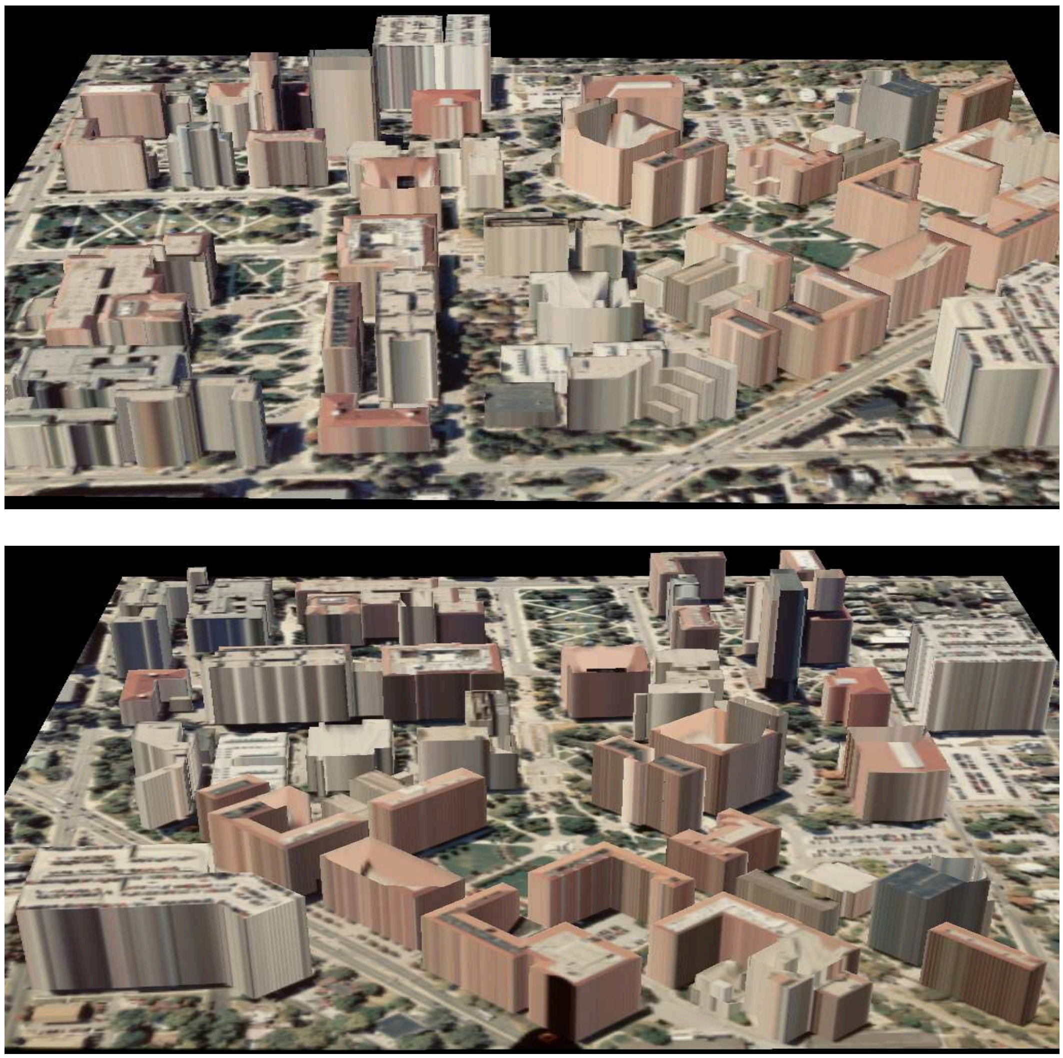


Figure 8. Photorealistic view of Purdue (East part)

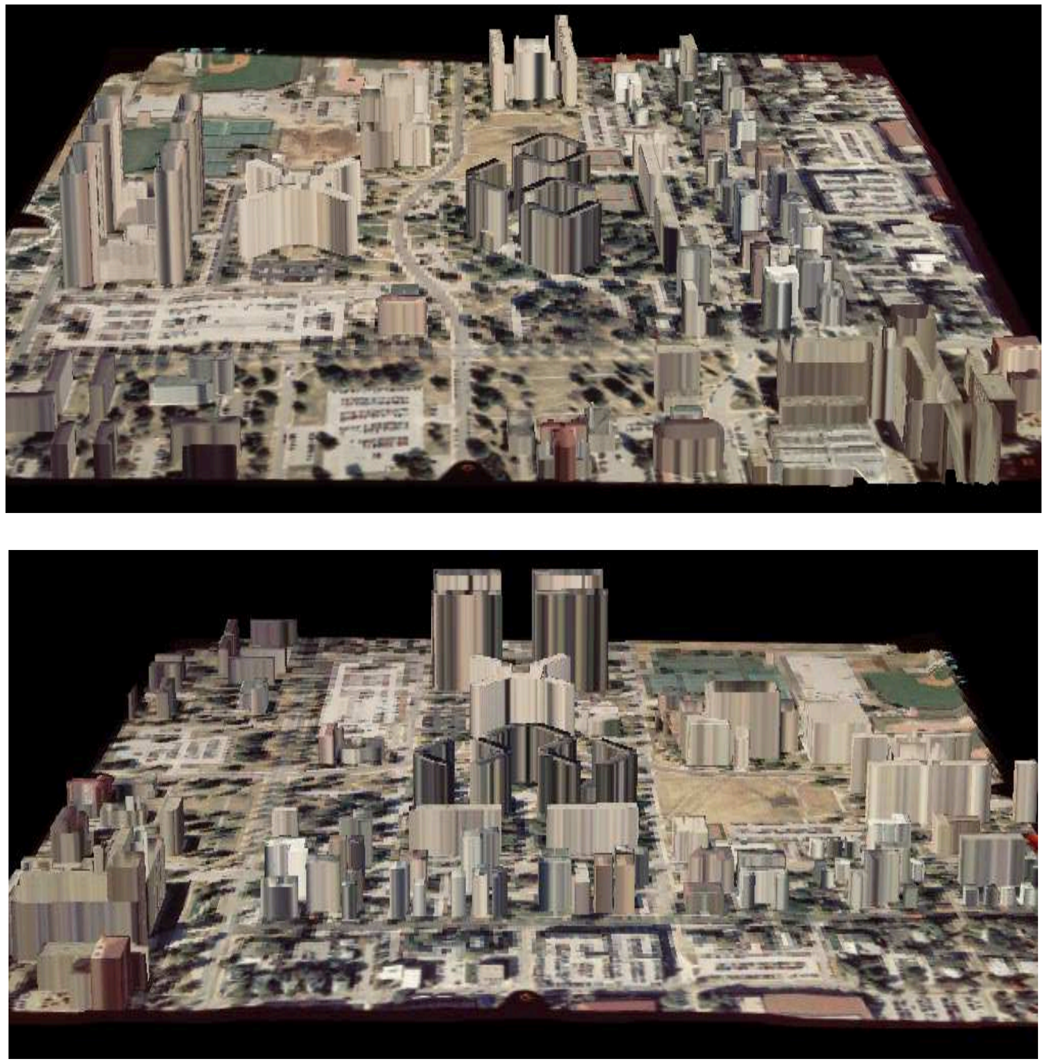


Figure 9. Photorealistic view of Purdue (West part)

SUMMARY AND CONCLUSIONS

GIS can be used as a useful tool for urban planning and other social and civil activities. Various available geographic data can be conveniently integrated, registered and geo-referenced within the GIS. To achieve a high level fidelity visualization, detailed urban features need to be collected and integrated into the GIS. Large scale photographs can be used as a good data source to delineate detailed urban features including buildings. To reach a photo-realistic view, the building topology needs to be exercised with caution, otherwise noticeable mismatching may be found when image textures are draped over the buildings. The TIN can serve as a convenient data structure to integrate the 3-D building model and ground elevation model for a photorealistic visualization. Future research efforts will be made on integrating stereo photogrammetry and 3-D CAD capabilities into GIS to truly model the complex buildings, their topology and texture.

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GIS AT WORK IN THE CRIMINAL JUSTICE SYSTEM

Abstract: How a GIS system can assist the prosecution efforts in a municipality. Presentation of a methodology to be used by the Minneapolis City Attorney's Office to gather data about certain crimes that are committed at specific addresses or neighborhoods within the city.

INTRODUCTION

The city of Minneapolis was founded in 1858 on the Mississippi River, and became a large milling community. Currently there are 370,000 residents in the city but over two million people frequent the city on a daily basis. It is home to General Mills, Pillsbury and has a large technology community connected with the University of Minnesota. The city is comprised of 85 diverse neighborhoods, 170 parks, and is called the "City of Lakes", as there are 26 lakes within its boundaries. Over the years, Minneapolis has evolved into many diverse communities with populations of varied ethnic, racial, cultural and economic backgrounds.

Minneapolis has always attracted immigrants to share in its prosperity and this continues today with over 70 different languages and dialects spoken in its schools. Access to affordable housing and services such as transportation and medical services encourage people of limited economic means to choose Minneapolis as a place to live. Many of these people require a disproportionate level of service, such as public safety, as they many have fewer economic resources and have a higher incidence of unemployment, family pressures or other issues that bring them to the attention of law enforcement either as a victim of a crime or as an offender. Many residents also see the city's Public Safety officers as the first responders to medical or other crisis situations when they have no where else to turn.

The Minneapolis Police Department is comprised of over 1,200 employees and 900 of them are sworn personnel. Their mission is to uphold the laws of the community. There are 5 police precincts including a Downtown Command. Each precinct is divided into geographic sectors, and the sector manager is tasked with reducing crime and responding to calls for service in the area of responsibility. They act as the Police Department liaison to local residents, property owners and business people.

The mission of the City Attorney's Office is to prosecute aggressively all misdemeanor, and gross misdemeanor charges in the city in order to promote public safety. The office is committed to aggressive prosecution of specific kinds of cases particularly domestic violence and DWI's. The criminal prosecution division has 31 prosecutors and 28 support personnel, as resources. Recently, since the mid-1990's, the City Attorney's Office has been asked to investigate and prosecute over 60,000 case yearly.

The increase in crime in the 1990's was due to the introduction of Crack/Cocaine. This lead to increased arrests and greater prosecution caseloads. As a result of those increases, the City of Minneapolis began to look for ways to reduce crime in the city. The goal of the Mayor and the

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