EXTRACTING HIGH RESOLUTION DIGITAL ELEVATION MODELS AND FEATURES IN A SOFTCOPY ENVIRONMENT

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ABSTRACT

Digital elevation models play an essential role in many mapping and engineering applications. With the introduction of softcopy systems, new technologies are available for both manual and automated DTM extraction and feature collection. This paper reports our experiences with softcopy systems and compares their performance and results to the traditional analytical plotter-based methods. The objective of our project was to test the feasibility of new softcopy DTM and feature extraction techniques for high density urban and suburban areas.

Traditionally, DTMs and features are extracted from "hard copy" aerial images on analytical stereoplotters. This process is supported by specialized photogrammetric software for image orientation, data extraction, and input to GIS-type database. Our approach used a softcopy photogrammetric workstation and digital aerial images. The images were obtained by scanning aerial diapositives at a nominal resolution of 25 micrometers on a Leica scanner. All the tests, including orientation and data extraction, were carried out on a Leica/Helava DPW 770 softcopy workstation.[1]

1. INTRODUCTION

New, emerging technologies often require a large volume of spatial data in an unconventional format. A typical example is the construction of cellular phone networks. In order to determine the optimal distribution of cells, i.e., where to build the radio transmitter stations, a careful spatial analysis is necessary to assess and model the electromagnetic signal propagation in the area. This process frequently requires an unusually dense representation of the surface including all natural and man-made objects. Furthermore, a key element of this data is the surface normal since signal reflections play a very important role in the analysis of the electromagnetic field. This necessitates a sub-meter grid representation of the area including terrain points, buildings, transportation structures, tree canopies, etc. This "draped" surface data is the primary input to the electromagnetic signal propagation analysis program which is built around a ray tracing algorithm. Different antenna positions are analyzed in order to arrive at the optimal antenna location. In an additional step, traditional GIS data about the usage of the cellular phones, such as the population demographics, traffic, and behavioral patterns are considered to analyze the capacity conditions and finalize the antenna positions. The currency of the data and quick turnaround times are also important aspects.

In cooperation with a cellular phone company, a pilot project was carried out at the Center for Mapping and the Department of Geodetic Science and Surveying in 1995. The objective was to deliver 1m grid data covering the combined surface of natural and man-made objects over two very dense urban areas with sizes of approximately 2km by

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[1] The Leica/Helava DPW 770 softcopy system was donated to the Department of Geodetic Science and Surveying, The Ohio State University, by Leica Inc. in 1995.

2km. The data quality requirement was a better than 1m absolute accuracy and better than 0.5m relative local accuracy (the key issue is the relative position of the antenna). Aerial photos of the two areas were scanned on a Leica scanner, and the entire orientation and measurement process was carried out on a Leica/Helava DPW 770 softcopy workstation.

2. EXPERIENCES

Two sites were selected for this project: the southern tip of Manhattan in New York City, and Silver Spring, Maryland. Both sites measured approximately one square mile. The first site is typical of a very dense urban area with high-rise buildings and tightly packed city blocks. The second site included downtown and suburban areas, with a less dense building distribution. Panchromatic imagery was obtained from an aerial camera with a nominal focal length (150mm) and scale of 1:24,000 for Manhattan, and 1:14,400 for Silver Spring, furnished by Air Photographics, Inc., West-Virginia.

Preparations

The interior orientation for the digital images was performed during the scanning process. The exterior orientation of three consecutive images on the softcopy workstation was accomplished by visual 3-D observation of ground control points, both horizontal and vertical. The built-in bundle block adjustment of the DPW 770 system delivered the final orientation data. Some check points were used. The RMS error for control points was in the 10cm range, while check points produced a 60-70cm RMS error. Since this orientation process is different from the usual two-step procedure which includes separate relative and absolute orientations, the models were set up on an analytical plotter for comparison. Due to the different model systems, direct comparison of the exterior orientation parameters was not possible; thus, check points were used to relate the quality of the orientations. Comparison of the readings on the Zeiss P1 analytical plotter with the softcopy data showed a reassuring correspondence (Schenk and Toth, 1989). Figure 1 shows the footprint and control point distribution for the block of the Manhattan project.

Prior to data extraction, epipolar resampling of imagery was done to avoid visual distortion in stereo viewing and to facilitate the use of the automated DTM extraction. The DPW 770 softcopy system offers two sets of tools for automatically creating and editing DTMs and building features, respectively. Thus, the data acquisition process consists of two basic phases: DTM extraction and feature measurements. Starting the sequence with the DTM extraction and continuing with the features or vice versa is a user option. In our investigations, both approaches were tested.

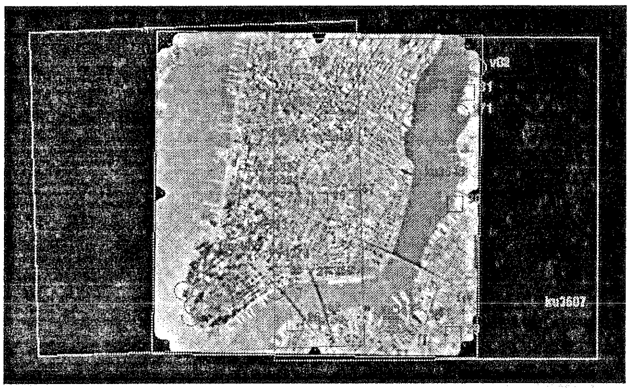

Figure 1. Footprint of the Manhattan site

In the first data extraction phase for the Manhattan site, building features were digitized from digital imagery by using DPW 770 "feature extraction" tools. These tools allowed us to follow a rooftop outline or building block in a number of operating modes, including: automatic rooftop, square, static, spline, and mixed (Socet Set, 1995). All of these digitization modes created the actual building volume; that is, the sides of a building were created automatically. This became possible by digitizing the elevation at ground level next to the building footprint. Once the building extraction was complete, the automated DTM extraction and editing were performed.

The same set of DTM and feature extraction tools was used for the Silver Spring site. The major difference, however, was in the building volume creation. Since DTM extraction had been performed before the features were extracted, the elevation of the nearest grid point from the DTM was used for building volume computation, and operators' input of elevation near the building footprint was not necessary. This sped up the digitization process but may have compromised the vertical accuracy.

Manhattan project

The project site targeted a square block on the east side of the southern tip of Manhattan. Considering the required large number of elevation posts, it was necessary to divide the entire area into eleven smaller subsites. Figure 2, showing a part of the area nicely illustrates the complexity of this very dense urban scene.

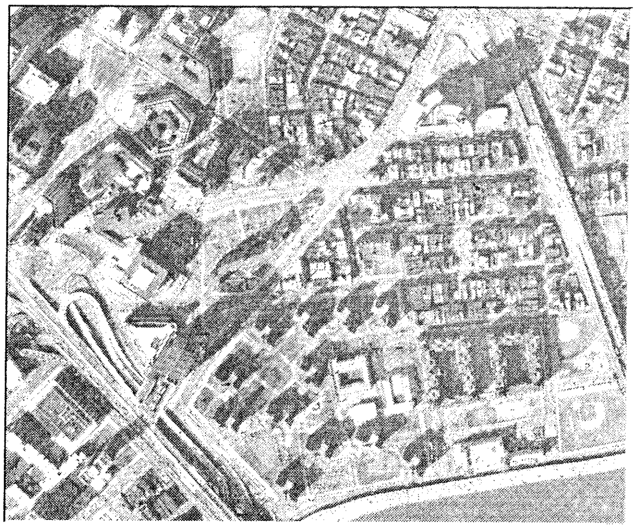

Figure 2. Detail image of the Manhattan site

Based on size and complexity, building structures were extracted differently. Blocks of smaller buildings attached to each other were measured as generalized features, while more complex structures were individually extracted. The vertical extension of the features was obtained by digitizing at their footprint.

The DTM extraction started with a larger 10m grid interval selected for initial processing and the required 1m by 1m grid spacing was obtained by densification. Several automated DTM extraction strategies were tested on small test areas. The one offering the highest accuracy, measured in Figure of Merit (FOM) and by visual inspection, was selected even though this selection frequently required extensive manual editing in areas of limited visibility (occlusions) and elimination of rooftop elevations. The average speed of automated DTM extraction was about 3600 points per minute in the strategy we have employed, which is a very impressive number. On the other hand, even the highest accuracy strategy applied, for automated DTM extraction, would yield lower vertical accuracy, compared with analytical plotter measurements, because of the image matching difficulties at this scale of photography. As an example, image matching in parking lot areas would give us ground elevations as well as elevations on top of cars, vans, and trucks. Another example is a highway overpass, where occlusions and different imagery of moving vehicles from two consecutive images cause difficulties. In those cases, the built-in DPW 770 interpolation methods that we applied produced slightly less accuracy, compared with direct elevation readout by an experienced operator on an analytical plotter. For the reasons stated above, once we determined initial DTM elevations, a number of editing tools were employed to create refined, ground DTM elevations. Figure 3 shows contour lines representing the terrain; the areas under the already digitized features were interpolated for completeness.

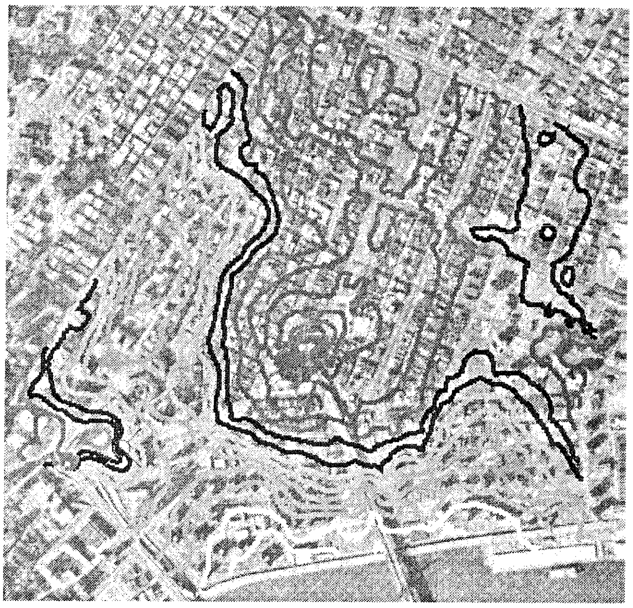

Figure 3. Terrain contour lines

The merged DTM areas combined with the features of the Manhattan site resulted in a total of 4,344,171 elevation posts at the 1m grid spacing. Obviously, it would not be feasible to obtain this type of DTM information from analytical plotters because of the time necessary to manually digitize such a large number of ground elevations (Toth and Schenk, 1990).

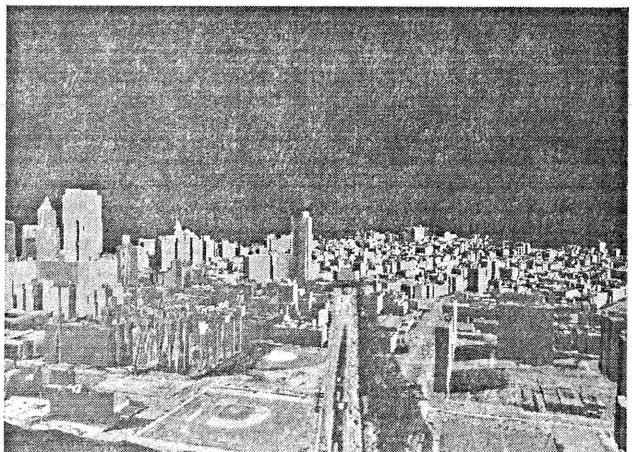

Figure 4. Perspective view of a mixed area

The visualization of the data was performed by generating a sequence of perspective views. Figures 4 and 5 show perspective views of the "draped" surface data, including a scene with various terrain and building structures and another one of less complexity. Note, that the side of the man-made structures are only shaded but not painted.

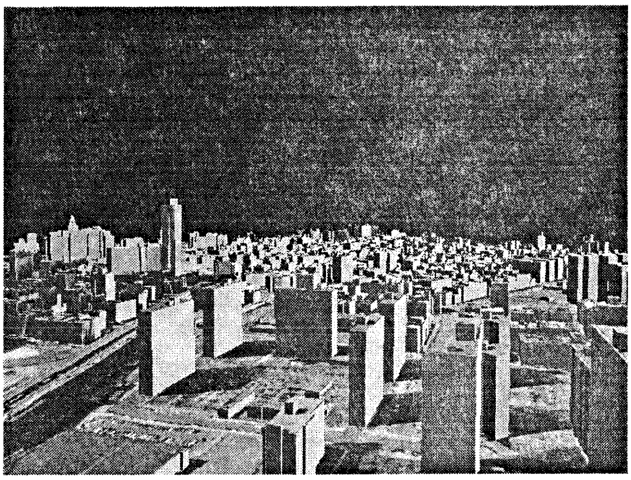
Figure 5. Perspective view of a less complex area

Silver Spring project

The DTM extraction for the Silver Spring site differed from the Manhattan area in a number of ways. The scale of the photography was larger, but more importantly, the terrain itself included wooded, suburban areas with single family housing units. Figure 6 shows the project area.

In dividing the project area into subsites, we had to carefully consider the differences between the characteristics of the suburban and downtown sections and decide which special strategies to apply (Helava, 1988). The critical issue in suburban type areas was to come out with a DTM strategy that would give "true" ground elevations in open areas while simultaneously yielding house rooftop elevations at the same time. Such a solution would immediately provide deliverables, i.e., the combined surface of natural and man-made objects. After performing several tests on typical areas, we selected the optimal automated DTM strategy for our objective, with the understanding that in wooded areas we would not obtain "true" ground elevations but elevations of treetops and bushes instead. Only prominent building structures in these areas would have their rooftop elevation digitized using feature extraction techniques.


Figure 6. Silver Spring project area

The downtown DTM area was generated in the same fashion as in the Manhattan project, where "true" ground elevations, without buildings, trees, and other obstructions were determined using multiple DTM editing tools. An initial 4m grid spacing was used to generate DTMs for the two downtown sites. Figure 7 shows a perspective view of the data including a single family housing area. The front of the image shows clearly the performance of the used DTM strategy. The rooftops rise out from the rolling surface of trees and bushes while the open areas such as the road in the center follow the terrain.

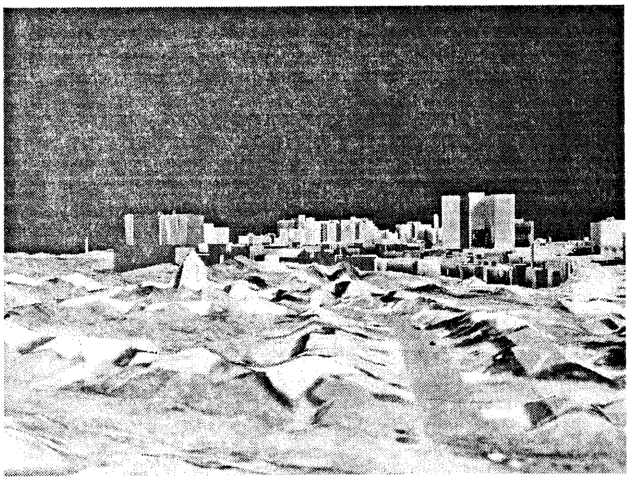
Figure 7. Silver Spring, suburban area

Figure 8 shows a mixed area with dense distribution of man-made features.

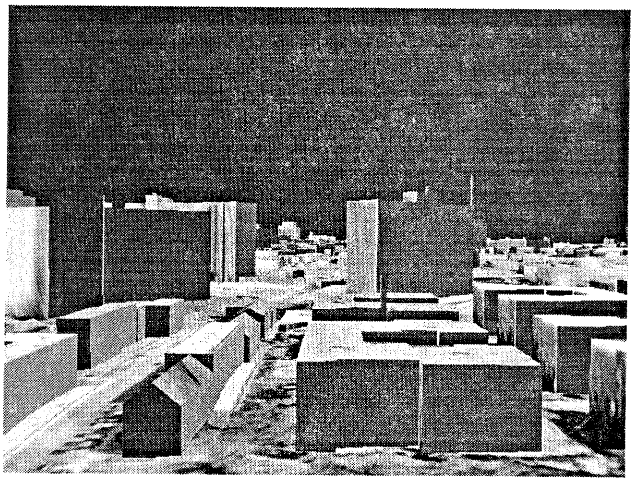

Figure 8. Silver Spring, business area

Figure 9 illustrates the quality of the automatically extracted DTM; also, to assess the need for editing, the distribution of FOM values is shown. The diagram covers two datasets, one over a typical suburban subsite and one with many building structures. As expected, there is a significant difference in the performance of the hierarchical correlation algorithm. Dense urban areas still pose a difficult task for any DTM scheme.

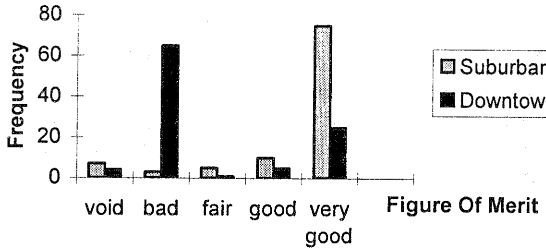

Figure 9. Distribution of FOM

3. CONCLUSION

In a summary, after individual processing of all the subsites in both project areas, the merged DTM areas of Manhattan and Silver Spring resulted in a total of 4,344,171 and 3,487,785 elevation posts, respectively. The number of building features extracted was 2640 for Manhattan and 1406 for Silver Spring. The Manhattan project required 140 hours to complete, while Silver Spring was completed within 76 hours. In addition to being more difficult, the Manhattan site was also slightly larger than the Silver Spring site.

Our experiences clearly show the tremendous potential of softcopy systems for automated or semi-automated DTM and feature extraction. The acquisition of very dense spatial data in such a large volume is unprecedented in traditional environment. Measuring this type of DTM information is possible, but obviously not feasible on analytical plotters, due to the lack of the support for the obligatory user interactions, and furthermore, because of the unacceptable labor requirements necessary to manually digitize such a large number of ground elevations. Since the automatic DTM extraction is a batch process, the key issue in softcopy environment is the effectiveness and the user-friendliness of the on-line editing capabilities and quality control tools and utilities. Our encouraging experiences have unmistakably demonstrated the power of softcopy systems. It has become clear that these systems can already efficiently compete with other existing methods. In addition, they can deliver data in many new, unconventional, formats, and thus, open up new applications for the use of high-volume spatial data.

In the future, we expect substantial improvements in the user interface, as well as continuous development of the built-in automated processing (Schenk and Toth, 1992). Currently, the efficient use of these systems requires a quite considerable amount of relevant knowledge. These changes will ultimately speed up the proliferation of the softcopy technology in the mapping industry.

4. REFERENCES

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