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The Generation of Digital Orthophotos and Three Dimensional Models of an Urban Area from Digital Aerial Photos

Jin-Duk LEE*

Abstract

The digital photogrammetric products have been increasingly used as an accurate foundation for representing information associated with infrastructure management. The technological advances in merging raster and vector data within the framework of GIS have allowed for the inclusion of DTMs and digital orthophotos with vector data and its associated attributes.

This study addresses not only generating DEMs and digital orthophotos but producing three dimensional building models from aerial photos of an urban area by employing the digital photogrammetric technology. DEMs and digital orthophotos were automatically generated through the process of orientations, image matching and so on, and then the practical problems, which must be solved especially in applying to urban areas, were considered. The accuracy of produced digital orthophotos was derived by using check points. Also three dimensional visualization imagery, which is useful in the landform analysis, and 3D building models were produced.

Digital photogrammetric products would be used widely not only as GIS framework data layers by using the GIS link function which links attribute and image information in the database for applying to infrastructure management and but as geospatial data for especially 3D GIS in urban areas.

Keywords : *Digital Photogrammetry, DEM/DTM, Orthophoto, 3D Building Model, GIS Framework Data, Digital Photogrammetric Workstation, Infrastructure Management*

1. Introduction

In recent years the great advance in the field of digital photogrammetry has further solidified the role of photogrammetry as data collection methodology, allowing the bypassing of the need for expensive, dedicated stage where automation through the use of digital imagery and suitable image analysis techniques have made the transition from research and development to production, with digital photogrammetric workstations.[2),3)]

The digital photogrammetric products which include DTM/DEMs, digital orthophotos, digital topographic vector maps and 3D visualization maps have been increasingly used as an accurate foundation for representing information associated with infrastructure management.[1)]

In any imaging system, each imaged point will have a particular perspective geometry and in order to view each pixel in an orthogonal projection the effects of terrain have to be removed. The DTM is used to model the relief variation which presents in the image and each pixel in the raw image is resampled into an orthogonal projection which the user can define. The orthophoto is vital, especially if perspective views are to be rendered for mission planning or visualization as this will ensure that all features are in their true position with respect to the underlying elevation model. It is also vital for use as an highly accurate, up-to-date base map for commercial applications, including database updating.

DTMs and orthophotos are two of the most popular and fundamental geoinformation layers at GIS.[4)] The technological advances in merging raster and vector data within the framework of GIS have allowed for the inclusion of DTMs and digital orthophotos with

*Member, Professor, Ph.D., School of Civil and Environmental Engineering, Kumoh National Institute of Technology (E-mail : jdlee@kumoh.ac.kr)

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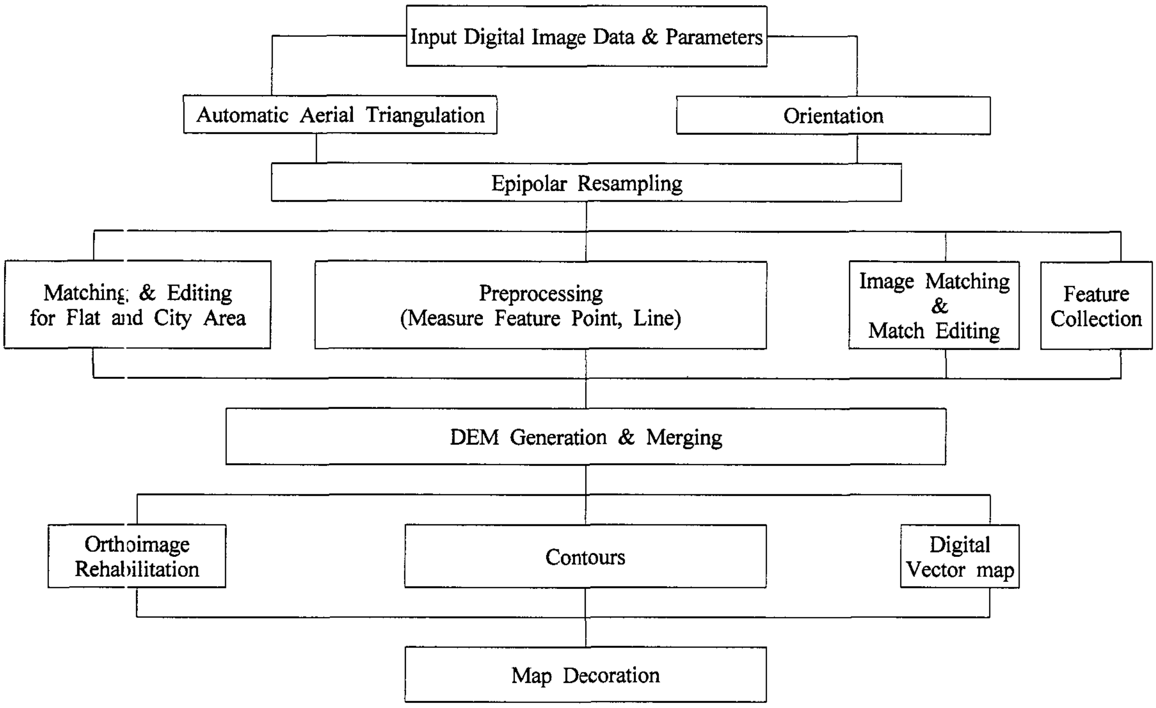

Fig. 1. The procedure of data processing using digital photogrammetric workstation (VirtuoZo).

vector data and their associated attributes.

The purpose of this study is to show generating not only DEMs and orthophotos but three dimensional building models from aerial photographs of an urban area employing digital photogrammetric techniques and to review the integration of digital photogrammetry and GIS. With the interactive manner of the digital photogrammetric workstation, DEMs and orthophotos were automatically generated through the process of orientation and image matching, and then the practical problems, which must be solved especially in applying to urban areas, were considered.

2. Data Collection and Processing

2.1 Preparation of Data Sources

The selected object area was properly covered with mountainous area and building area and the data sources, which were taken at height range of 800 to 1000 meters by Wild RC20 with a focal distance of 153.59mm, consisted of five photographs along a strip with about 68% overlap at the scale of 1 to 5000. The positive films were scanned on a Carl Zeiss PhotoScan TD with 21 microns or 1200 dpi. The resulting ground coverage per pixel was approximately 0.106 meter.

Because scanned photographs are just image data, the coordinates of ground control points should be acquired by field surveying or from large-scale digital maps and so on. Ground control points were surveyed with the rapid-static GPS technique using carrier phase measurement mode for about 7 to 10 points each model. The positions of points employed as control points are for example flower bed cornor, manhole, cross of lane line and stop line in roads, end points of bridges and so on. The WGS84 coordinates of the points obtained by GPS were transformed into Korean transverse mercator coordinates based on Tokyo Datum.

The procedures involve with the digital photogrammetric workflow which can be categorized into three primary sections of aerotriangulation, DEM/DTM generation and ortho-rectification. The block parameters which include ground control point data, camera calibration data and stereo model information were

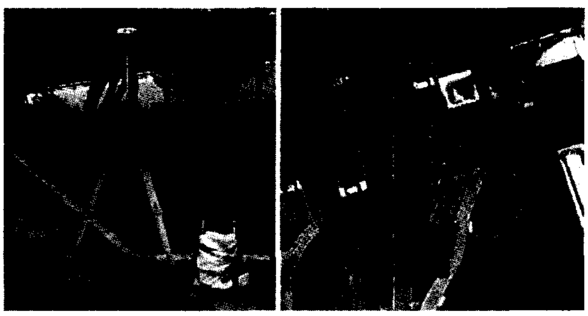

Fig. 2. Ground control surveying with GPS.

entered first and then processing in interactive manner was conducted according to the procedure represented in Fig. 1 on VirtuoZo Digital Photogrammetric Workstation.

2.2 Orientation and Image Matching

Interior orientation is the procedure of knowledge of fiducial marks and automatic location. When cross mark is overlaid on any one of eight marks, the other marks were automatically located. Considering displayed residuals, those measurements were precisely adjusted. Resulted average residuals of interior orientation were 6㎛ in x and 8㎛ in y direction.

Relative orientation is the procedure of finding conjugate points in the other photo of a stereo pair. The number of those points depends on the photo quality. In this study the number of found conjugate points were between 70 and 120 each stereo model.

In absolute orientation, ground control points surveyed with GPS were entered by pointing and click. Average accuracy of absolute orientation was 0.123 meter in X, 0.091 meter in Y and 0.054 meter in Z direction

Epipolar image resampling make the array of left and right images have the same geometry for detecting rapidly matching points while conducting image matching. In this study the bilinear interpolation technique was employed for image resampling, which interpolates linearly the values of the nearest four pixels. Stereo images were resulted from image matching carried out based on a pair of epipolar images.

The VirtuoZo has stereo capabilities using CrystalEyes active shutter glasses.[5] Fig. 3 shows a stereo image which resulted from matching conducted based on a pair of epipolar images. This system uses crosscorrelation for image matching, and also uses another global relaxation matching technique at the end phase in order to check whether the matching results of each point are consistent with the results in its neighbourhood and thus detect blunders.

In this study the patch size that was used for crosscorrelation was 9×9 pixels and the distance between match points was 9 pixel, i.e., 0.95 meter in object space.

3. Generation of DEMs and Orthophotos

3.1 DEM Generation

In this study, on the DEM generation module(DEM FC) of VirtuoZo triangulated irregular networks(TIN) were formed and then grid DEMs with one meter spacing were extracted using uncontinuous points and mass points, which were added to be suitable to real topography, distributed randomly in a relatively plane urban area.

Since some blunders may always remain in the data set, a manual editing will still be necessary. The system provides certain indications of the matching quality and means to edit the data. VirtuoZo divides the points into three quality classes that are displayed on the screen with different colours.[5] The worst class includes points that have been interpolated.

Uncorrected DEMs make digital orthophotos distort especially in built-up areas with high buildings. Elevations were corrected confirming equivalent parallax curves on each stereo model. After DEMs were edited and then image matching, TIN formation and grid DEM extraction were conducted again in order (Fig. 4).

3.2 Digital Orthophoto Generation and Mosaicking

With scanned photos, DEMs, orientation elements

Fig. 3. Editing of a matching image.

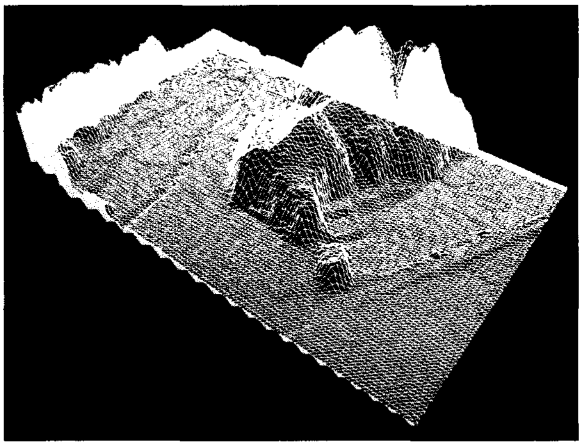

Fig. 4. Digital elevation model extracted from a model.

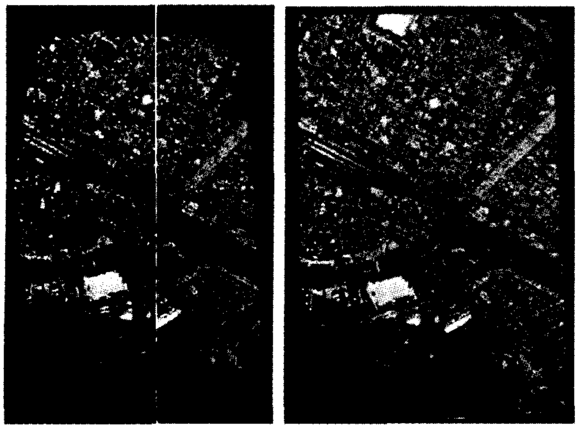

Fig. 5. Comparison of digital orthophotos between correction and uncorrection of DEM in the built-up area.

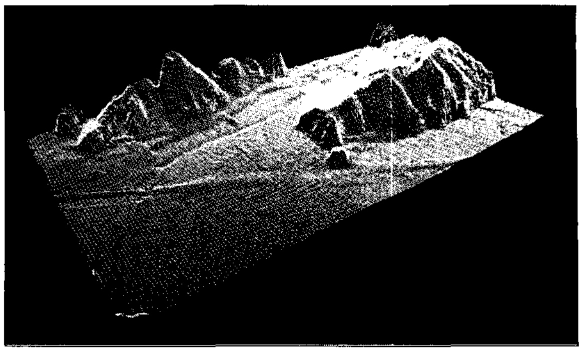

Fig. 6. DEM merging for the entire study area.

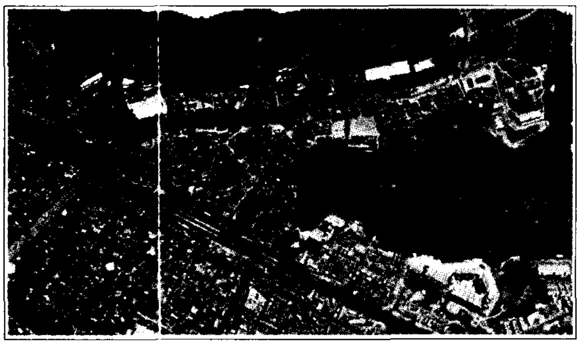

Fig. 7. Orthophoto mosaic image for the entire study area.

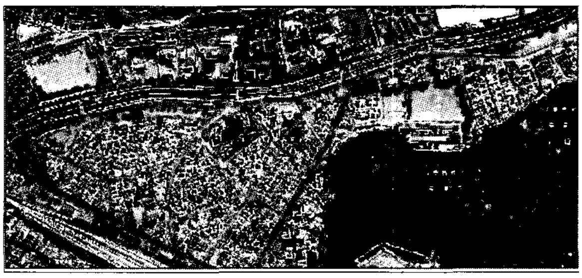

Fig. 8. Digital orthophoto map overlaid by contour and road layers.

and ground control point data the orthophotos were generated which have the scale of 1 to 1000, the resolution of 300 dpi and the ground sample distance (GSD) of 0.0846m.

Fig. 5 shows two orthophotos generated respectively with and without DEM correction. It was ascertained that the DEM correction resulted in removing abnormal height points, reforming the shape of roads and rivers correctly and the edges of buildings clearly.

To meet the requirement of continuous image data for the whole study area, DEMs and orthophotos generated from four continuous stereo models were merged or mosaicked (Fig. 6 and Fig. 7).

Fig. 8 shows the digital orthophoto map in which the road and contour layers of digital topographic maps were overlaid on the digital orthophoto. It includes both quantitative information of existing maps and qualitative information of image data.

3.3 Accuracy of Digital Orthophotos

The accuracy of produced digital orthophotos was derived by using 26 check points selected on digital topographic maps with the scale of 1 to 1000. As the result, accuracy was RMS errors of 0.2 meter in X and 0.55 meter in Y and so the RMS error of 0.59 meter in plane position. These errors are within ± 0.75 meter that is the tolerence limit of plane positional accuracy in the regulation of Korea digital topographic map production with the scale of 1 to 1000.

And compared with 20 ground control points surveyed with GPS, the plane RMS error was 0.23 meter and maximum errors were 0.29 meter in X and 0.46 meter in Y direction.

4. Visualization and 3D Building Modelling

The 3D perspective view imagery is useful for the landform analysis, urban and highway planning, river management, housing site development and so on. It gives the effect that one actually looks down at the terrain from different view points. 3D perspective images were produced by resampling pixels of digital

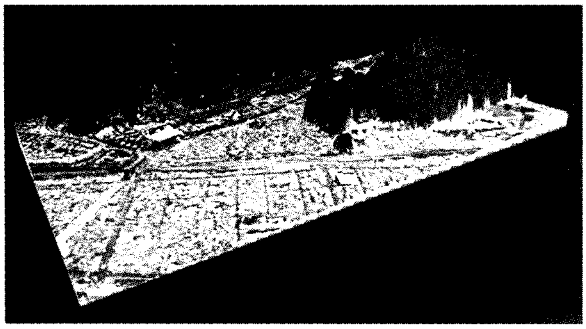

Fig. 9. 3D perspective view.

orthophotos on DEMs.

It is difficult to represent break lines by a specific grid spacing of the DEM. Therefore the DEMs were corrected into real building elevations inside building edges to extract correctly the DEM of the building area. And then 3D building modelling was performed using the IGS module and the Cybercity module of VirtuoZo NT Digital Photogrammetric System.

The elevation data and edge plot data of buildings, which were obtained in the IGS, DEMs with one meter spacing and orthophotos were fused in the Cybercity module and then building surfaces were textured to enhence visual effects of building modelling. 3D models of built-up areas visualize easily city skyline and can be utilized as important data for landscape planning and landscape analysis.

5. Consideration of Uses within GIS Applications

Uses with GIS applications can be divided into two primary types; those requiring height information(the DTM) or derivatives like slope, aspect and so on and those requiring high precision base maps(the orthophoto), either for backdrops or as a source of vector data.[6)]

Fig. 10. DEM of the built-up area.

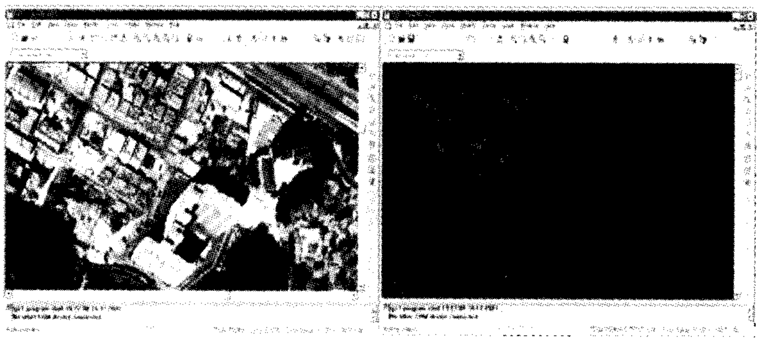

Fig. 11. Building edges plotted on a stereomodel by using the IGS for 3D building modelling.

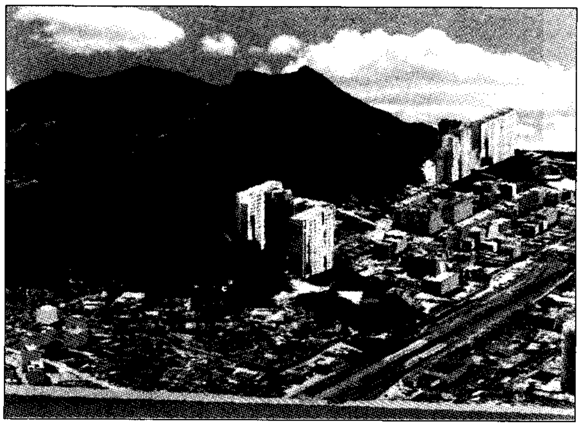

Fig. 12(a). 3D modelling of the city area.

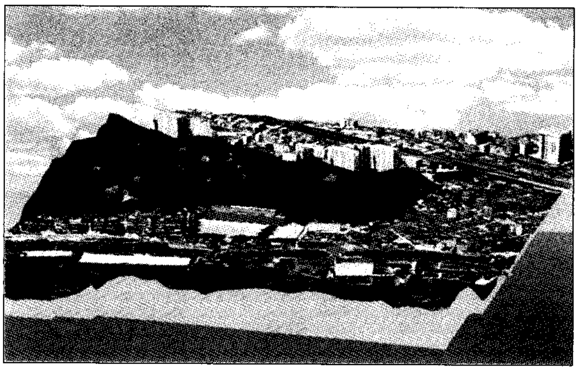

Fig. 12(b). 3D modelling of the city area.

Many spatial modelling applications, such as site location and route planning require height derived 'layers' as part of the process. DTMs can also be used in visualization, specifically in environmental and military applications. The siting of new facilities can first of all be generated using the spatial analysis described above. The proposed site could then be viewed in 3D, with the facility added to the DTM, either by adding a polygon of the appropriate value of height in mono view of by accurately adding the height of the facility in stereo. This enables the user to check on its visibility from surrounding areas. Viewshed analysis can also be used in the opposite sense to show if your own location can be seen from other areas for the purposes of concealment.

Orthophotos provide the most accurate and up-to-date base maps. Many natural resource management applications now simply use a symbolized base map instead of a complex vector based map. However, the largest demand for orthophotos lies in the data provision aspect of GIS. An orthophoto can be used for generating vector map and other measurement information directly from the computer screen by simply using the mouse to digitize vector map information (and attributes) directly from the orthophoto on screen, using the computer as a monoplotter. This de-skills the entire vector generation process and hence reduces the cost of creating the database. As this is normally the major cost component of a GIS system, digital photogrammetry is a way of reducing that cost.

Currently typical GIS operates on a 2.5D mode, with a single z-value attributed to a point(x,y), often through the use of DTM information. Within an integrated photogeographic information environment we are moving to full 3D data. The move towards fully 3D GIS is also supported by the potential for the fusion of aerial with terrain digital imagery and 3D building models extracted from it. No longer are simple planimetric views enough, with users demanding perspective views and real time flythroughs. The softwares with the 3D GIS capability allows the 3D image to be queried in real time and this is new direction in GIS where the real world can be modelled, analysed and queried in 3D on the desktop.[4]

6. Concluding Remarks

One of the problems in generating digital orthophotos of an urban area is that break lines each building should be considered in densely built-up areas. The other is that large-scale aerial photographs taken with wide angle cameras make building images lie own. So using middle-scale photographs taken with normal angle cameras in built-up areas had been presented as its alternative.[2]

Accuracy of digital orthophotos generated in this study was estimated experimentally as 0.22m in X and 0.55m in Y direction. With the fusion of digital elevation models and digital orthophotos 3D visualization like a 3D perspective view and a 3D building model could be conducted using the digital photogrammetric workstation.

It is easy to appreciate the advantages that are brought to the production of terrain databases and derived products such as orthophotos with the introduction of well developed software algorithms, combined with the increasing availability of powerful desktop workstations.

Digital terrain models and orthophotos serve as foundation base maps from which ground features can be mapped. Digital photogrammetric products would be used widely as GIS framework data layers by using the GIS link fuction which links attribute and image information in database for applying to infrastructure management which may be watershed management, cadastral mapping, utility line planning infrastructure, airport planning, transportation planning and modelling and so on.

It is now possible to generate digital terrain models and orthophotos when required on standard available hardware. More importantly, the information can be generated on demand to the exact density, area and quality required by the particular project.

It is also expected that digital photogrammetry would be used as an efficient technology for collecting and processing geospatial data for especially 3D GIS in the urban areas.

Acknowledgements

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