Effective Generation Method of the Geospatial Information to Build a Flood Hazard Map

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1. Introduction

A research & development work has been going on to generate a flood hazard map to enhance the preparedness to the flooding thereby minimizing the damages of the floods. To generate such a flood hazard map; the modeling process should be made at the first stage. And securing topographic data with acceptable accuracy is the essential part to complete such a modeling process.

The major objectives of this study was to investigate the various methods of generating topographic data using different types of source data and to propose the most efficient methodology to support the modeling process.

2. Generation Methods

This study mainly concentrated on the generation of the DEM(Digital Elevation Model) for numerical analysis especially for the flood modeling. The DEM generation process could be divided into two parts: data acquisition and data processing. The data acquisition included a process of three dimensional positional data and the quality of the DEM was closely related to the types of the raw data and the data selection method used. The data processing mainly interpolated the elevation values for the unknown points using a model calibrated by the sampling data.

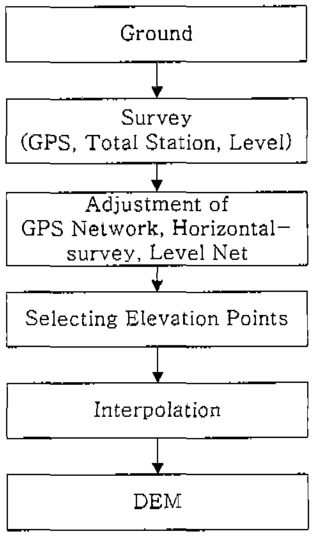
2.1 Data Generation Method

The data generation method to obtain DEM could be divided into two types: direct method and indirect method. The direct method--to obtain the data directly from the surface--were ground survey, interferometry, and SAR(Synthetic Aperture Radar). The indirect method was extracting topographic data from indirect remotely sensed data such as aerial photography, satellite imagery, existing paper maps, or digital maps.

The direct method normally had some disadvantages in spending higher cost to collect data therefore interpolation method using sampling data has been widely used. The optimal approach was to acquire elevation data with the least sampling points satisfying accuracy criteria considering time and cost.

2.1.1 Ground Survey

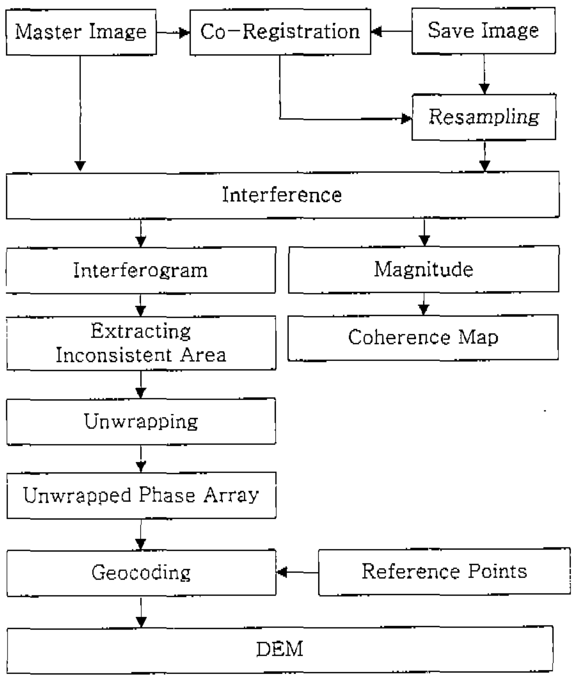
The DEM acquisition from the ground survey was relatively higher accuracy since the sampling points were determined based on the topographic characteristics (Figure 1). However, this method was only able to apply for the smaller area due to the higher cost and more time-consuming comparing with other methods. Therefore, the ground method only could be used for the smaller area, calibration of the topographic data, or evaluation of the DEM. The major equipments to use the method were total station, GPS, and level, etc. The GPS data could be obtained 24 hours' period a day without any impacts from the weather. However, the GPS had some communication problem from blocking by the high-rise buildings in urban areas. The total station could be used effectively in the urban area with an accuracy of the few centimeters. The leveling also provided the accuracy of the few millimeters and has been widely used for the DEM acquisition for construction work or facility maintenance, etc.



<Figure 1> Ground Survey

2.1.2 Interferometry SAR

The DEM data from the Interferometry SAR were obtained from the Radar data using two receivers. The equipments were SAR dispatcher, receivers, and GPS antenna. Figure 2 showed the procedure to get the DEM using the SAR mechanism. The interferogram was made from only using the principal phase, which enabled the phase unwrapping. The interferometry SAR was cost-effective for the data collection and processing, and it had the less impacts from the weather and time with the applicability for the wider area of the photography. The most critical issues in interferometry was the phase unwrapping. The method to get the optimal solution for the phase unwrapping was based on the mathematical approach such as the Least Square Method, Discrete Fourier Transform, Discrete Cosine

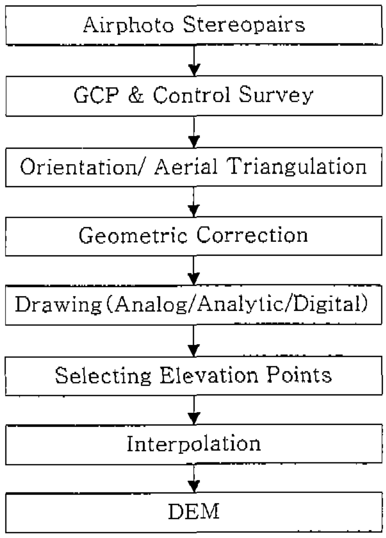


<Figure 2> Interferometery SAR

Transform, and Fast Fourier Transform, etc. Also, there was significant difference in processing time according to the algorithms used. And the level of credibility of the processing algorithm was relatively low due to the less application to generate the topographic data.

2.1.3 Aerial Photography

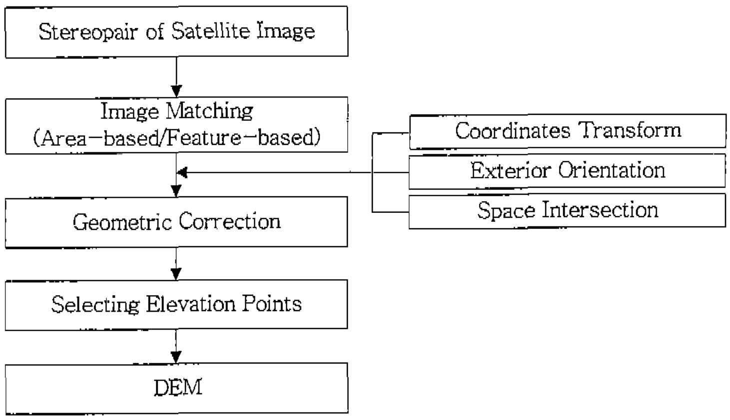
The acquisition of the DEM data using an aerial photography could be made using a pair of the stereo airphotos and a stereo plotter. The accuracy of the DEM was affected by the scale of the airphotos. This method produced, in general, the better accuracy than other methods. However, the analytic plotter with an encorder took more time and manpower, so that this method had some disadvantages to produce a DEM in the case of applying for the wider area. Figure 3 shows a procedure of DEM generation using the airphotos. Four different methods could be used to generate the DEM after the editing of the true-position using the ground survey data: regular method, density-increment method, mixed method, and contour method.



<Figure 3> Aerial Photography

2.1.4 Satellite Imagery

The satellite image-based DEM acquisition was mainly based on the analysis of the stereo images facilitated by the image processor. The elevation was obtained from the X-position variation of the left and right matching points based on the geometric correction and strereo matching techniques. This was made using the images scanned at left and right side of each different position. For this, the ground coordinates for individual pixels were identified and the map-matching to identify the same point from a pair of the stereo model should be made (Figure 4).

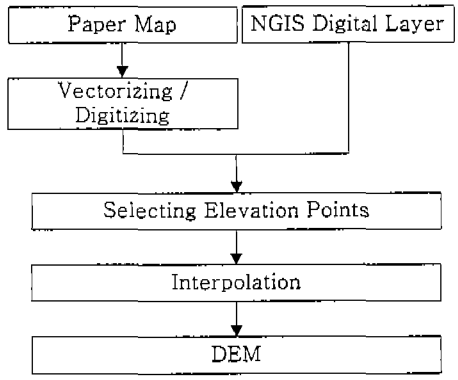


<Figure 4> Satellite Imagery

The satellite image-based method has been spreading and this was proved to be cost-effective and less time-consuming. However, this method had the disadvantages of the difficulty in getting an optimal values during image matching and inducing errors to accompany matching-errors and lengthening processing-time. The errors of the DEM generation using the satellite imagery was affected by the spatial resolution of the images, the characteristics of the scanned objects, the sampling points, the experience, and the capacity of the system used. Although the automatic matching techniques could be categorized into numerous classes, in general, the area-based matching and the feature-based matching were the major types.

2.1.5 Digital Map

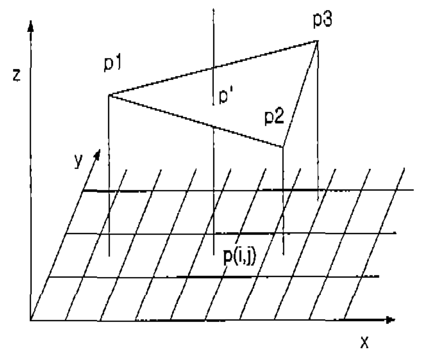
The DEM could be also made using the paper maps or NGIS digital layers. This method was comparatively low-cost and enable to generate for the wider area. Figure 5 showed the DEM generation procedure using the digital layers. The major disadvantages of this method was the difficulty in extracting the elevation points as the elevation data concentrated on the contour lines, and the loss of the data. The accuracy was depending on the quality of the paper maps, the contour intervals, the maneuvering experience, and the capacity of the system. The achievable accuracy was the half of the contour intervals used.



<Figure 5> DEM Generation

2.2 Data Interpolation

Interpolation was provided the elevation data for the area with no sampling data. It was not desirable to collect the field data for all the area considering time and money. So, interpolation was definitely needed using the sampling data for more effective DEM generation. A suitable interpolation method could possibly represent the types, accuracy, importance, and the characteristics of the topographic features. The interpolation methods generally used were Nearest Neighbor, Inverse Weighted Distance, Inverse Square Distance Weighted Interpolation, Bilinear, TIN, etc.



<Fig 6> TIN based Linear Interpolation

The Nearest Neighbor was the most popular method and selected the height of the closest point from the unknown point. The Inverse Weighted Distance considered the impacts of the distance by counting the weights from the inverse of the distance to provide the better estimation of the elevation data. The Inverse Square Distance Weighted Interpolation took the inverse of the square of the distance so that the closer points to the unknown point could have more weights. The Bilinear Interpolation assigned a weight based on the area instead of the distance. The TIN-based linear interpolation used three height values and these could be used for interpolation for any point within a triangle. For example, Figure 6 used a linear equation $z = ax + by + c$ to get the height values for any given point.

3. Discussion

3.1 Comparison

Among the direct methods, the ground survey provided the highest accuracy and the credibility although this was the most cost-expensive. The interferometry was considered to be most cost-effective comparing with the ground survey, however, the interpolation algorithm and cost-effectiveness were not yet proved for practical uses especially for the cases of the developing countries. For the practical use of the interferometry, more research and development efforts were to be made.

In indirect methods, DEM from the paper maps or the digital maps seemed to be the most effective data, however, the quality of the paper map and the digital layers were the dominant factor to decide the adoptability of the DEM.

Considering the currency of the data, the DEM generation from the airphotos and the satellite imagery was relatively efficient way, especially considering generation cost. The satellite imagery was superior in terms of providing data currency and cost-effectiveness while inferior in providing enough spatial resolution.

The most effective method, so far, could be the combined method of satellite imagery and digital layers. The satellite imagery could provide the currency and cost-effectiveness while the digital layers provided relative higher accuracy of the geometric correction--which could hardly get from the satellite imagery in some cases--and ground reference data.

3.2 Accuracy

The accuracy from the interpolation was also analyzed using the DEM generated from the 1:5,000 digital layers (Table 1). Table 1 showed the interpolation results of the average heights, maximum and minimum heights, dispersion, and standard deviation for Suwon area. The table showed that TIN based linear interpolation had the smallest deviation and dispersion while the others had the higher values. In other words, the TIN based linear interpolation provided the least magnitude of the errors.

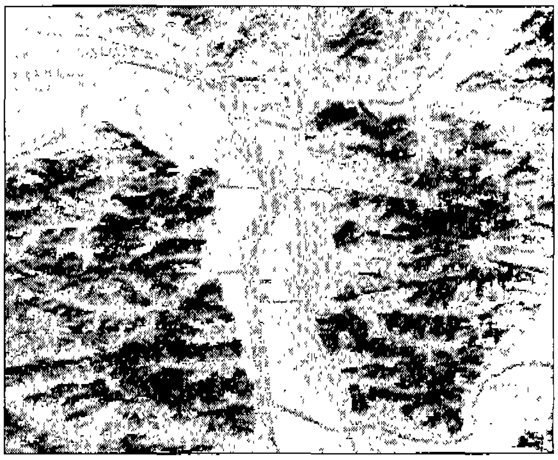
<Table 1> Comparison of the DEM Interpolation Methods

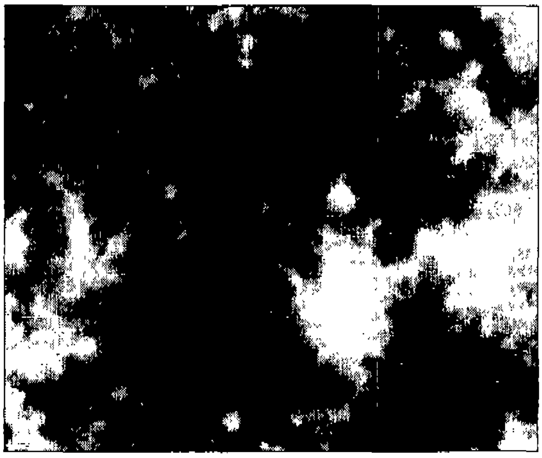
Interpolation methods	Average	Minimum	Maximum	Dispersion	Standard Deviation
Nearest Neighbor Interpolation	108.2	53	335	2164.11	46.52
Inverse Weighted Distance Interpolation	108.3	53	335	2156.24	46.44
Inverse Square Distance Weighted Interpolation	108.2	53	335	2158.90	46.46
Bilinear Interpolation	108.4	53	335	2150.18	46.37
TIN based Linear Interpolation	108.2	49.56	325.4	2091.7	45.74

3.3 Data Securing for Critical Area

The DEM generation method described in 2.1 was easily applied for the area which had airphotos, paper maps, or digital layers. However, some areas with neither paper maps nor digital layers proposed the higher level of difficulty to generate the geospatial information for the modeling to generate the flood hazard map. Such area, so called the critical area, has been a major target to establish a method to generate the DEM only using a few data sources such as satellite imagery or airphotos. One of the example of such critial area--Munsan area with frequent flood damages--was selected for this study to identify an effective method to generated the DEM.

The SPOT satellite data with a pair of the stereo panchromatic image was obtained and the DEM was made using a PCI S/W. Since there was no recent paper map, 1:25,000 topographic maps were digitized and used to provide the boundaries of the major streamflows and urban area, with some remarkable landmarks. Figure 7 showed a SPOT imagery used to generate the DEM(Figure 8). The results showed that the DEM generated from the SPOT imagery could be used for the purpose of the flood modeling since it provided the level of submeter DEM.





<Figure 7> SPOT Image of Munsan Area　　<Figure 8> DEM Generated from SPOT Image

4. Conclusion

This study analyzed the possible method to generate a DEM for flood modeling to see the boundaries of the damaged area. Also, the interpolation method was investigated to see the adoptability. The results showed that the direct and indirect method could be used once the source data available for the study area in a effective way. Also, TIN-based linear interpolation provided the most least error amounts in data calibration.

The critical area, which had no basic data such as the paper maps or any digital layer, was analyzed to identify the most effective DEM generation method. The results showed that using the satellite imagery with digitized layers from the dated paper maps was the only and possibly effective way of generating a DEM.

Further study need to be made to secure more effective and sound methodology in terms of cost, accuracy, and procedure. Also, considering the portion of the critical area in S.Korea with no enough data sources, more research work should be made to secure topographic data. More satellite imagery-oriented work probably be desirably considering the availability of the satellite data around the country. However, auxiliary data sources such as the paper maps or airphotos need to be secured to enhance the satellite image's spatial resolution and geometric correction.

5. Acknowledgement

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