

APPLICATION OF HIGH-RESOLUTION (10M) DEM ON GEOGRAPHIC INFORMATION SYSTEMS

Masatoshi MORI

Department of Management Engineering, Kinki University
mori@fuk.kindai.ac.jp

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ABSTRACT:

A high-resolution Digital Elevation Model (DEM) (10m meshed grid) has been integrated with Geographic Information Systems (GIS). So far, 50m-meshed DEM by the Geological Survey of Japan (GSJ) is widely used for various GIS applications such as constructing 3D systems in Japan. 50m DEM covers all over the area of Japan, which has 0.1-meter resolution in a vertical direction. The spatial resolution of 50m DEM is, however, not enough for precise requirements from cartographic designers, developers, and civil engineers. Recently, 10m-meshed DEM has been developed by a commercial cartographic company, which also covers all over the area of Japan, and has 0.1-meter resolution in a vertical direction. The minimum unit of 10m DEM file corresponds to the second level mesh code, that is, a 1/25000 topographic map defined by GSJ, which is composed of 1000 lines by 1000 pixels. This format is quite convenient in integration with GIS. The GIS data constructed by Kitakyushu City in Kyushu area in Japan is used for the present analysis. This GIS data has many quite precise features such as not only roads, public area, etc. but also individual housing area, water supply lines. Kitakyushu City Office surveys the city area by aerial survey once for one year or two years, which takes much cost at each time. And also, an IKONOS one-meter high-resolution pan-sharpen image has been integrated with GIS at the same time. An affine transformation has been carried out to integrate an IKONOS image with GIS, in which the RMS error of 30 GCP is finally reduced to 0.4 pixels, which are quite good. Then, the IKONOS image is pasted on a surface of 3D structure constructed by 10m DEM. As a result, the detailed 3D view on a surface with an IKONOS image overlaid with roads, and another features is obtained. It is found that the integration of high-resolution DEM and high-resolution satellite images with GIS could be substituted for conventional aerial survey. In the present research, ArcGIS 8.2 (ESRI) is mainly used as a GIS analysis system for PC Windows.

1. INTRODUCTION

1.1 Digital Elevation Model in GIS

Recently, Geographic Information Systems (GIS) is commonly used in various fields beyond traditional digital mapping systems such as classifying 2D maps, network analysis of roads, evaluation of power lines candidates, etc. Especially, 3D visualization by GIS is widely used in these few years. However, 3D GIS needs high accurate elevation data of ground. The previous elevation data are rather rough in spatial resolution, so it was difficult to use them in urban area. We use elevation data as digital elevation model (DEM) in GIS system. DEM is a digital file consisting of terrain elevations for ground positions at regularly spaced horizontal intervals.

In the United State, the National Elevation Dataset (NED) is available through the U.S. Geological Survey. NED has a resolution of one arc-second (approximately 30 meters) for the conterminous United States. Although these data are very useful for 3D GIS analysis, 30-meter resolution is not enough in precise analysis.

2. DIGITAL ELEVATION MODEL IN JAPAN

2.1 50m DEM

50m-meshed DEM by the Geological Survey of Japan (GSJ) is widely used for various GIS applications such as constructing 3D systems to create three-dimensional representations of the

area in Japan, so far. 50m DEM covers all over the area of Japan, which pixel has 16 bit levels corresponding to 0.1-meter resolution in a vertical direction. And 50m DEM data are available in quite low cost. The spatial resolution of 50m DEM is, however, not enough for precise requirements from cartographic designers, developers, and civil engineers.

2.2 10m DEM

Recently, a commercial company (Hokkaido Tizu) has developed high-resolution DEM up to 10m horizontal meshed model with 0.1-meter resolution in a vertical direction, which also covers all over the area in Japan. 10m DEM is quite effective for various applications of GIS. A unit file of 10m DEM in 1000 pixels by 1000 lines is exactly corresponding to one of 50m DEM, which is the second meshed code by the GSJ standard.

The comparison of difference between 50m DEM and 10m DEM is shown in Figure 1. Figure 1(a) shows a 3D visualization of 50m DEM with colour coded, and Figure 2(b) shows one of 10m DEM. The difference of spatial resolutions is very clear. The spatial resolution of 10m DEM is comparable to one of 4m multispectral IKONOS imagery.



Figure 1(a). 3D view of 50m DEM



Figure 1(b). 3D view of 10m DEM

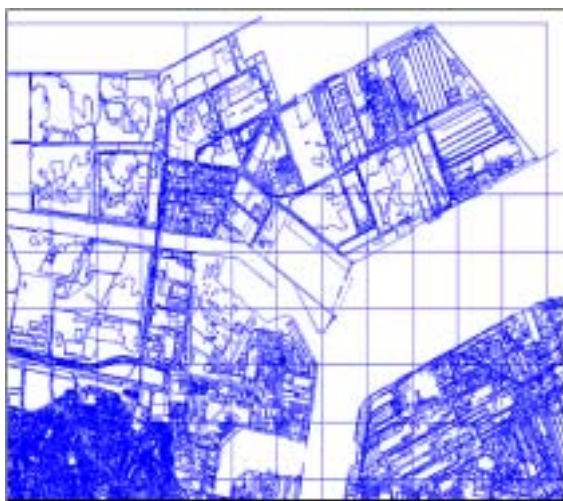


Figure 2. Precise GIS Map

3. INTEGRATION OF 10M DEM WITH PRECISE GIS MAP

3.1 Precise GIS Map

First, it is necessary to prepare reference data as a basic scheme so as to create 3D GIS system. In the present study, a precise GIS map by Kitakyushu City in Japan has been used as a digital map, which is quite accurate. A part of the map is shown as in Figure 2, which shows near a coast of the City. The map is updated in every year by Kitakyushu City Office, which consists of standard features such as roads, railroads, highways, stations, major buildings, and bridges, but also individual residential area.

3.2 Integration of 10m DEM

There are two ways to integrate 10m DEM with a digital map. The first one is to integrate 10m DEM in a shape file format, which format is basically a vector type, so it is easy to perform it. Integration from a shape file is suitable to visualize a 3D image using TIN (Triangulated Irregular Network) as a global surface model. A part of 3D view by using TIN is shown as in Figure 3. Although triangulated network is highly dense in areas with high undulation of land surface, it is not dense in areas with low undulation.

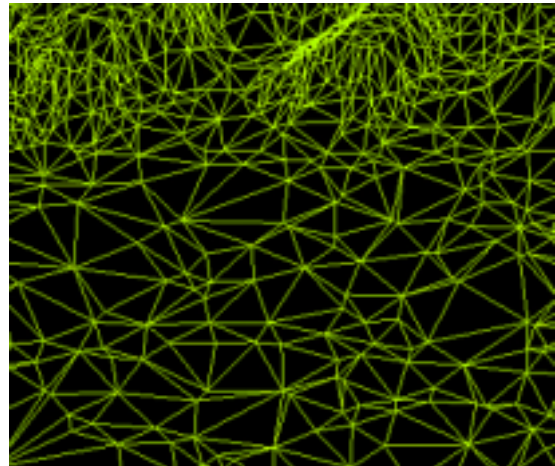


Figure 3. A part of 3D view by using TIN

The other one is to use a raster data format as original Tiff file. This method is direct processing of all points, which gives its elevation to each point. In a case of processing from raster data, elevation data are given even in plane area. However, processing time in raster data is much larger than that in using TIN.

3.3 Integration of IKONOS Imagery

In order to obtain 3D surface model on GIS system, high-resolution satellite images have been used for integration with a digital map. As satellite image one-meter pan-sharpen image from IKONOS satellite is adopted for land surface covers. One-meter resolution images are sufficient for resolution of 10m DEM. Figure 4 shows the IKONOS image corresponding to Figure 2.



Figure 4. IKONOS colour image
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An affine transformation is performed for integration of IKONOS image with a digital map. There are several problems in combining a raster image and a vector image. Especially, it is difficult to select GCP in vector images correctly, because the images are symbolized, and elements in a digital map are not corresponding to a satellite image in pixel level (one-meter resolution). On the other hand, it is easy to select GCP in satellite images. Then, we have chosen central lines of roads as feature layer in GIS. We show a sample for selecting GCP in each image, using snapping effect. Thus, GCP for transformation are selected for 30 points over the image, equivalently. After several trials, the RMS error of 30 GCP is finally reduced to less than one pixel, which are comparatively good. The result of integration of IKONOS images with a digital map is shown as in Figure 5.

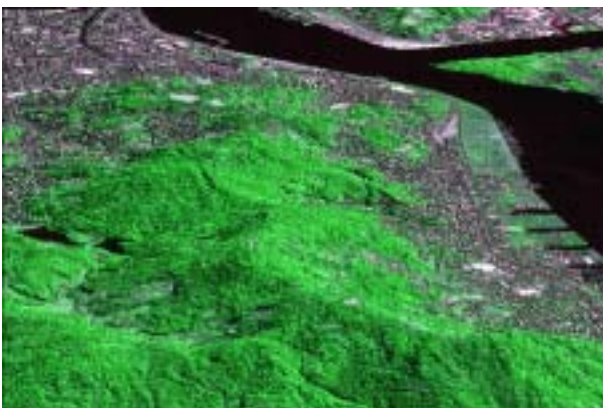


Figure 5. 3D view of IKONOS image
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4. APPLICATION OF 3D VISUALIZATION OF SEDIMENT DISASTAR

4.1 Heavy Rainfall Disaster in the Kyushu District in Japan

Between two days from 19 to 20 in July 2002, a heavy rainfall attacked Kyushu district in Japan, which had caused many kinds of disasters in various areas (Ushiyama, 2004). Especially, a sediment disaster in Minamata City, Kumamoto prefecture, was largest in this season, and 19 civilians were dead due to this disaster. Basically, occurrences of a sediment disaster in mountain areas depend on not only soil state, but also 3 dimensional structures of land slopes. In this study, 3D visualization of landform, where the sediment disaster occurred, is created using 10m DEM and aerial photos.

4.2 Integration of 10m DEM and Aerial Photos

A 1/25000 digital map by GSJ is adopted as reference data for Minamata City area. A precise digital map in local areas is not so popular such as ones in large cities, so a standard 1/25000 digital map is used. 10m DEM including Minamata City is integrated with the reference data, which is shown in Figure 6. The aerial photo, taken on 22 in July, is shown in Figure 7, at which point the sediment disaster has occurred.

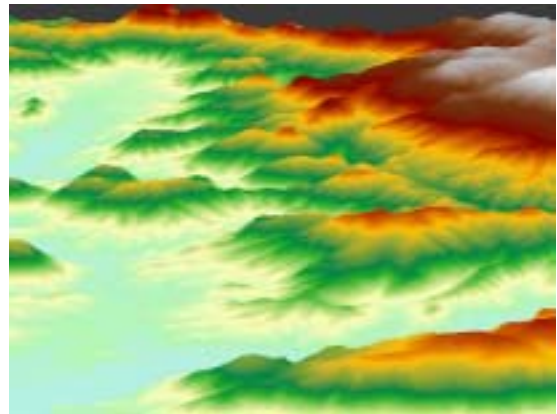


Figure 6. 3D view of 10m DEM in Minamata City



Figure 7. Aerial photo at occurrence of the sediment disaster

Figure 8 shows series of aerial photos including Figure 7. Figure 8 is obtained by processing the orientation of multi-photograph. Figure 9 shows a 3D view of Figure 8, obtained by pasting aerial photos on 10m DEM surface. Figure 10 shows 3D view of a full scene.

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Hokkaido Tizu Co. <http://www.hcc.co.jp/index.shtml>.



Figure 8. Series of aerial photos

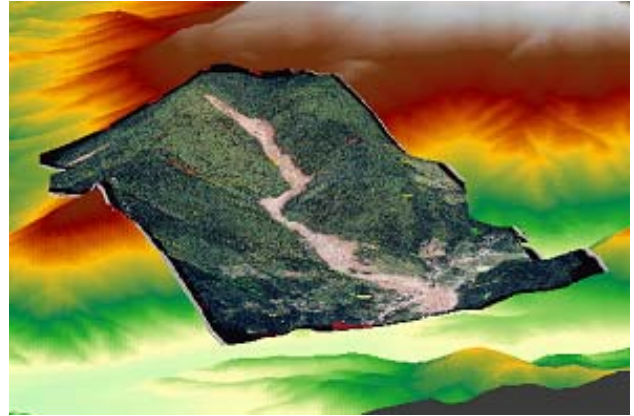


Figure 9. 3D view of aerial photos on 10m DEM



Figure 10. 3D view of a full scene