

**VECTOR DATA IN SEMI-AUTOMATIC CORRECTIONS OF DENSE DEM
FOR ORTHOIMAGES GENERATION.**

Renata Jędrzycka
Olsztyn University, Poland
Department of Photogrammetry and Remote Sensing
renata.jedryczka@kfit.uni.olsztyn.pl

Working Group IV/2

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ABSTRACT

Fully automatic generation of dense DEM from aerial images on urban areas is usually not sufficient in a accuracy for orthoimage creation particularly in the large scales. The correction process of DEM needs a lot of additional manual or semi-automatic techniques and it is time consuming.

The paper presents the method using additional information from existing vector data (f. e. from databases or from files including local measurements) to localise and correct DEM areas of buildings and their surroundings. All calculations were made with the self made software*.

1 INTRODUCTION

The automatic generation of DTM/DEM is in these days the conventional technique used in all digital photogrammetric workstations. They create files of heights data of various kinds of organisation, usually in regular or irregular grid of object co-ordinates. When we work with images in large scales (e. g. 1:5000) and particularly with the build-up areas or with poor texture we need more additional information. (Krzystek , 1998, Ackermann, 1996). It could be taken as the inner information from the images themselves or as the outer from data bases. The existing maps for example can serve as the information of localisation of the buildings (Paško , 1996) or roads (Roux,1996).

In this paper the data in the irregular grid were used because they were the original results of fully automatic DEM generation from two stereo images on the basis of area based technique. The additional information has been introduced on the last step of the pyramid of the images. These new data were stored as the vector data. The plane co-ordinates describing the building were taken into account. So only geometry of the objects was considered. The proposed method also used the operator as one of the elements of decision what to do next in step by step DEM calculation process. In the end the dense grid DEM was generated using bilinear interpolation. The grid size was determined by pixel size of orthoimage.

For accuracy checking the collection of points was made by manual measurement from images using the same self-soft-system, so only influences of interpolations and introduced outer information can be taken into account. The errors of Z calculations determined by all orientation processes has been omitted (without changing generality in relative comparison of heights).

2 SOURCE DATA

The first step was to obtain the data from automatic process of DEM generation from two images. The area based method with correlation coefficient as the similarity measure was implemented. The all levels of pyramid were used to create collection of Z data. In the object co-ordinate system they gave the irregular located points.

The calculation process is usually finished when the size of surroundings is bigger than the distance (in the object co-ordinate system) between centres of orthoimage's pixels. If images were taken on build-up areas it can look like in the Figure 1. There exists a lot of empty parts because correlation coefficient was too small or even not calculated.

* We used programmes made by dr Z. Paszotta: pyramid of images , automatic generation of DEM, determination of orientation parameters, and author himself; all in Windows NT/95,98 environment.



Figure 1. The dots represent the places with Z value generated in the automatic process of DEM generation: on the left- white dots are projected on the left image, on the right- black dots are projected on XY plane of the object space with scale dependent of size of user window and original image pixel size.

The most Z values calculated on the roofs of the buildings and in the areas of shadows are wrong. Very often we have additional data with measurements of various objects like buildings, roads, paths etc. . We used such set of data to add lack height information and correct the wrong ones. Only the roofs of the buildings have been taken into account. These data stored in the file have been visualised on the screen both on the image (using projection and Z value) and on the XY plane. You can see in the Figure 2 that some of Z values are wrong.

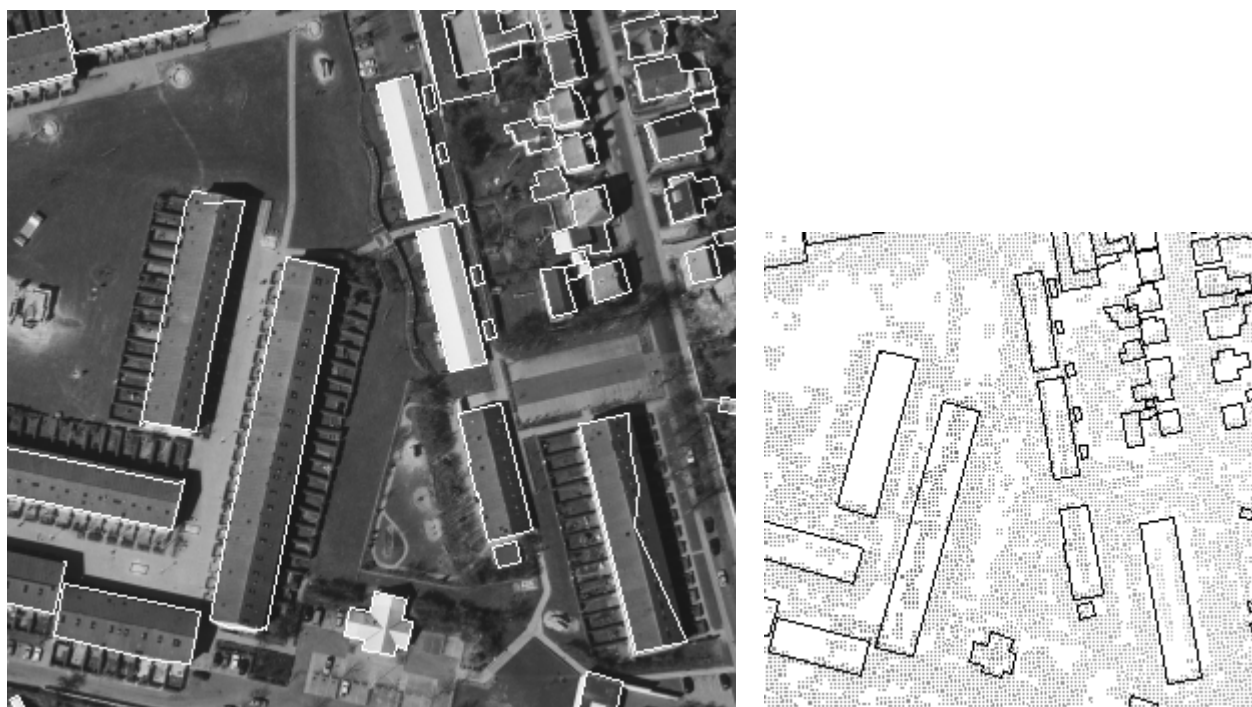


Figure 2. The projection of the vector data : on the left on the image (Z values were used), on the right on the XY plane with results of automatic Z generation.

3 DATA CORRECTION

3.1 Main steps

The main idea of the method is to use the vector data to clean elements in DEM file suiting areas covered by buildings. All calculations have been performed not in the image but in the object co-ordinate system.

First the roofs of the buildings have been automatically detected on the XY plane and only closed contours have been chosen. For this the algorithm of finding the closed contours has been implemented. It was necessary because of data type (ascii files with X,Y,Z co-ordinates and codes describing types of objects and points and lines). It has also been made automatically.

Afterwards the operator indicated the area which was later cleaned on the screen and also appropriate elements in DEM file were removed. Some objects not found automatically could be detected and cleaned manually by the operator just clicking on the borders of selected object on the left image. Using projection on the XY plane the areas were localised. The histogram of the selected area of Z values is accessible so the operator can determine the minimum and maximum Z values to remove Z values lying outside them from it.

We can't, of course, forget about discontinuities (introduced manually) and detection large height differences in X and Y directions (automatically checked gradients). All mentioned above things serve to have as many points as possible as lying just on the ground.

That way the first step (cleaning) has been finished and results you can see in the Figure.3.

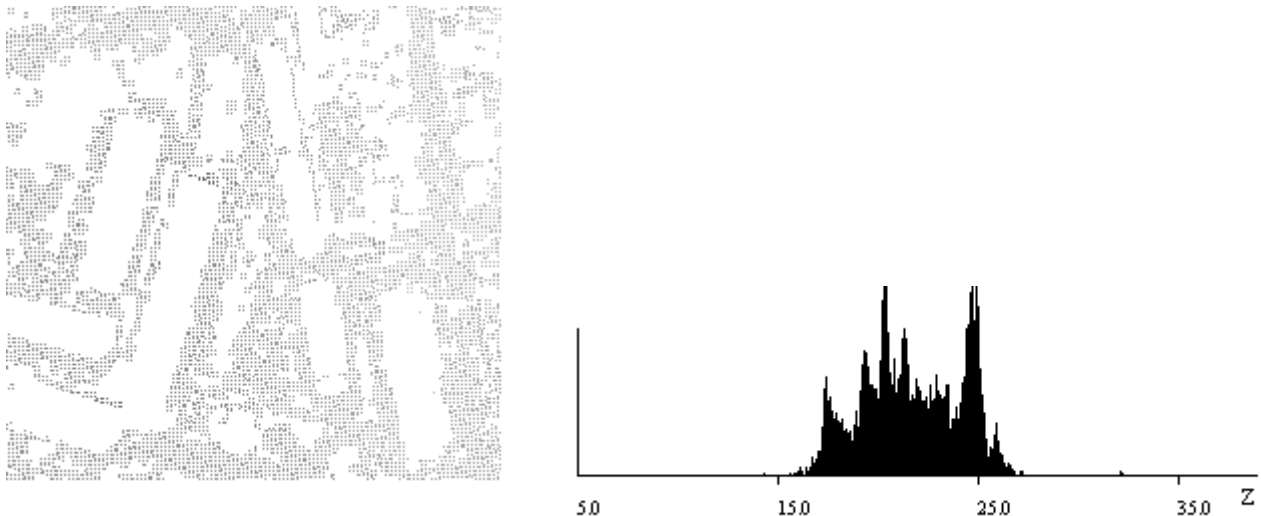


Figure 3. The region with the cleaned areas (on the left) and appropriate histogram of Z values (on the right).

The second step is connected with adding new information of Z values (filling). It also uses interactive tools. Namely, we can add separated points measured straight on the images (with the help of stereoscopic view) and polygons of fixed Z value. The external data stored in data base tables can also be used now.

Still empty areas are automatically covered by interpolation of weights average from neighbouring points in the iteration process. Smoothing of the area is controlled by calculating the gradients both in X and Y directions and by automatic checking the curvatures. After many iterations (the criteria are the fixed gradients and curvatures connected with the type of surface) we received smooth dense file without holes.

The third step concerns the creation of dense Z value file depending on orthoimage scale. The Z are interpolated by bilinear interpolation method.

3.2 The accuracy

The absolute accuracy of DEM is closely connected with the accuracy of calculation of all the orientation coefficients and with the process of automatic generation of the points from stereo images. We were concentrated only on the influences of cleaning and filling up processes on relative accuracy. Particularly filling can be one of the more disturbing elements. So we use a set of checking points for permanent control after every new operation. We take points measured manually on the images using for calculation object co-ordinates the same coefficients as in automatically generated DEM. In this way we can compare Z values before and after every iterations. The detached (in comparison with fixed value) values are monitored on the screen so the operator can check the region manually.

We used weights average in calculating absent Z values. The new Z is calculated by

$$Z = \sum_{i=1}^n w_i * Z_i \quad \text{where} \quad w_i = \frac{Z_i}{\sum_{i=1}^n Z_i} \quad n=1..8, \text{ depending of numbers } Z_i < > 0 \quad (1)$$

If we assume that errors of Z values are numbers from interval (m_1, m_2) , where $m_1 = \min_i Z_i$, $m_2 = \max_i Z_i$ ($i=1..n$)

$$\text{then new Z value has error } m \leq \frac{m_2}{m_1} * m_2. \quad (2)$$

Because should be $m_2 \cong m_1$ then $m \cong m_2$ so error couldn't be much bigger then m_2 - maximum of errors of neighbouring Z. Only the newly calculating points are taken into account. The data added from outer sources should also have errors not bigger then $\max m_2$.

4 EXAMPLE

The black and white images in scale 1:5000 were used as the test data. They have been scanned with pixels of $15\mu\text{m}$ that means that the image pixel size was about 0.075m. The accuracy of vector data were 0.1-0.2m.*

We usually need to correct much wider regions than the places covered by the buildings themselves so if pixel is 0.075m it is more than enough.

The smallest window in the automatic DEM generation was 21 x 21 pixel, on all the levels of pyramid, consequently the shortest distances between points in original Z file were about 1,58m. To generate orthoimage in the scale, for example, 1:2000 on screen with the resolution 100 dpi we should have the Z file with the grid about 0,53 m. The generation of it started when the original Z file was dense (without holes) and smooth enough. In the Figure 4 we have DEM for area 197m x 189m corresponding with area in the Figure 1 and 2. In the interactive process the buildings are removed.

In this area 26 checked points lying on the ground were selected. They were taken manually from images with the help of stereoscopic visualisation. The maximum difference in Z values of these points with Z generated in dense file was 1,2, the $s_0 \cong 0.22$ m and r.m.s. $\cong 0.06$.

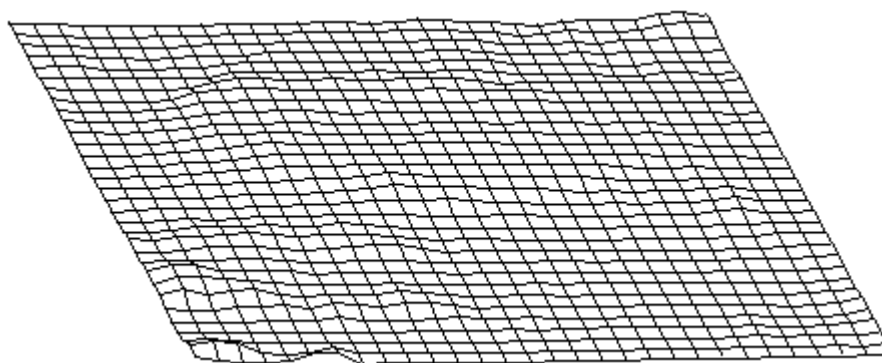
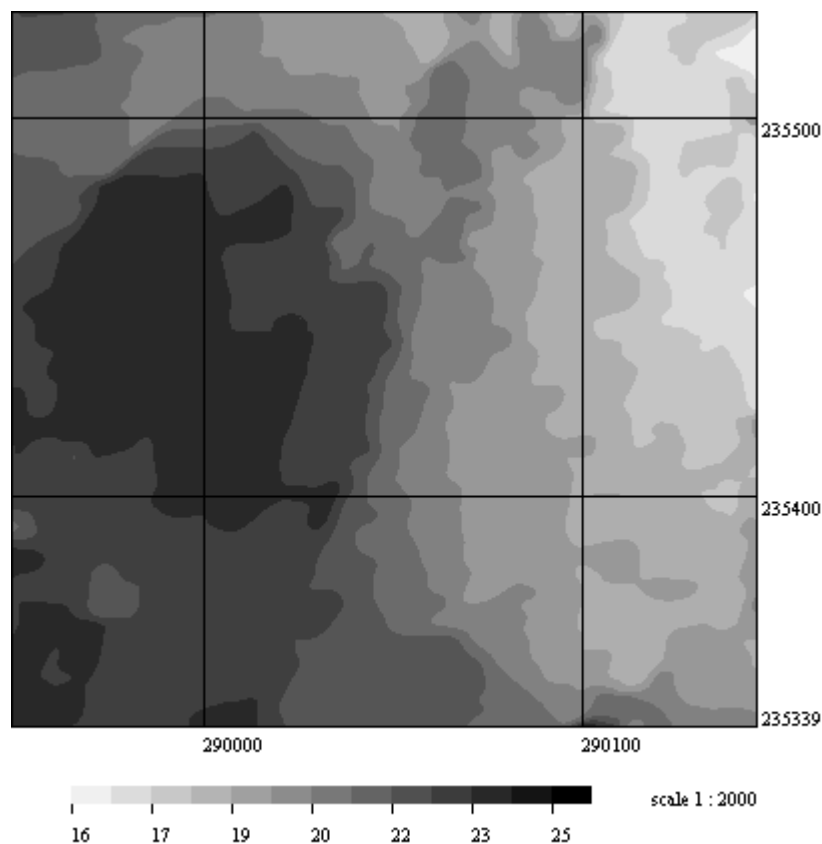


Figure 4. Dense generated DEM of selected region with grid size about 12.6 m (corresponding with $8*21$ pixels in the original image).

We received the ground-DEM where grid corresponds with pixel size in orthoimage after bilinear interpolation. In the Figure 5 we have the visualisation in grey scale of ground-DEM (without buildings) generated for orthoimage in printing scale 1:2000. Checking the Z values on the 20 draining holes taken from vector data we have the maximum difference of about 1.5m on 1 point, only 3 points about 1 m and 16 in interval (0.1; 0,6) and $s_0 \cong 0.61$ and r.m.s. $\cong 0.2$.

* All test data we received from the Aalborg University in Denmark at the opportunity of OEEPE test "Automatic orientation on data base information" (Jedryczka, 1999).



5 CONCLUSIONS

In this paper we present the way of DEM production in urban zones for orthoimage which assumes to generate first DEM on the ground and then add the building- DEM. We generate DEM straight from images. The proposition concerned using the existing vector data in the most possible automatic way and in that way decreasing manual measurements. The main idea was to short the time needed for generation a dense DEM for orthoimage generation. We have shown this on the fragment of the whole area because this work should be done on small fragments of the image. That gives the possibility to control visually successive results.

In dense build-up zones the fully automatic method doesn't seem to be realistic. Automatic extraction of buildings from images is necessary if we have not enough rich outer data information and it can serve as a good source of bringing them up to date. To have really good (in accuracy) DEM of built-up areas we first need good ground-DEM in regular grid (for example collected systematically from various kinds of information not only from images) and good data bases of man made objects. The combination of these two in interactive process can give expected results.

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