

# A WEB-BASED APPROACH FOR ONLINE DIGITAL TERRAIN MODEL AND ORTHOIMAGE GENERATION

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## ABSTRACT:

Currently, the Digital Terrain Model (DTM) and orthoimages have become standard geospatial products. However, photogrammetric systems used for generating them still remain desktop or workstation based systems. This paper outlines an innovative concept of DTM generation and geospatial image orthorectification over the Internet. The article contains description of algorithms for automatic DTM and orthoimage construction. DTM is an element that is necessary in the process of creating orthoimages and has a crucial influence on their cartometric attributes. Thus, it is extremely important to determine sources of errors that can influence the accuracy of the Digital Terrain Model constructing photogrammetric methods. Last part of the article contains presentation of Internet application dedicated to DTM and orthoimage construction and their quality assessment. Several Java client-server web applications were developed. In practice the application of the proposed algorithms is based on the system of a central unit (a server of applications and Web pages) and customer computers equipped with standard Internet browsers. It is possible to access this application from the Internet site of Department of Photogrammetry and Remote Sensing UWM in Olsztyn (<http://www.kfit.uwm.edu.pl/zp.html>) by selecting the "Orthophoto generation" projects. Opportunities of networked DTM generation and image orthorectification have had a great impact on the development of geo-information processing.

## 1. INTRODUCTION

New technologies have always been a key driving force in geographic information science. The Internet has opened up fantastic new opportunities for applications. There is an abundance of powerful, inexpensive personal computers and mobile devices that can access the Internet and run these new applications. The Internet also provides a new possibility for visualization of aerial and satellite images and other mapping datasets (Dai, et al., 2007). The needs of geospatial information obtain in the near real-time is also important for example to change detection or environmental monitoring. One of such data source is orthophoto image and DTM (Digital Terrain Model) that have become standard geospatial products. However, photogrammetric systems have used for generating them still remain desktop or workstation based systems. People in particular geodetic, architects or town planners, who wants to use topical orthophoto image to his study, has neither suitable photogrammetric photos nor appropriate software to process them. The opportunity of networked orthorectification come with modern information technologies has had a great impact on the development of geo-information processing.

This paper outlines an innovative concept of DTM generation and geospatial image orthorectification over Internet. The article contains description of algorithms for automatic DTM and orthoimage construction and presentation of Web application based on algorithms mentioned previously.

## 2. ARCHITECTURE OF WEB PHOTOGRAMMETRIC APPLICATION

The nature of web-based applications lend themselves to an n-tiered approach (Petersen, 2009). A typical application usually includes three essential elements: presentation, logic and data. Presentation represents user interface, logic refers to processing, and data refers to database or database management system. The relationship between these elements is that one element makes a request to the other element and the other element then fulfills the requests. The element that makes request is called a client and the element that fulfills the request is called server. A web application is one of the example the client/server model implementation (Peng, Z., Tsou, M., 2003). A 3-tier architecture is the most common approach used for such applications today. In the typical example of this model, the web browser acts as the client, an application server handles the logic, and a separate tier (database server) handles database functions (Petersen, 2009).

In the physical client/server model, a client refers to the computer that interacts with the end user and the server refers to the computer that manages and stores data and/or other processing functions.

In constructing a Web photogrammetric application, it can be assumed that the best quality of photogrammetric data (especially aerial photos and very high resolution satellite imageries) was stored on expensive, well-equipped data servers. Software that is necessary to read data from these servers was installed on another computer called an application server. Moreover, users have been communicating with the application server by means of their own software. Because we have a web-based application in mind, the client used a web browser for

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this task. When the client communicated with the application server the HTML code of the web side and short programs - called applets have been sent as a response. Actions on the server side have been conducted by programs called servlets. Applets and servlets are written in the JAVA programming language and compiled to bytecode, which at runtime is either interpreted or compiled to native machine code for execution.(Graba 2003)

The scheme of distributed application described above was shown in the figure 1

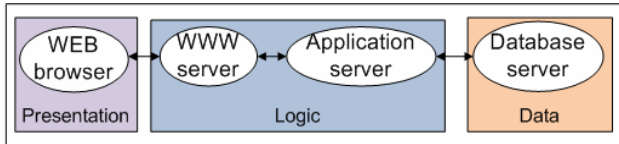


Figure 1. Architecture of web photogrammetric application.

In order to the web application presented in this paper acted correctly it is necessary to have a WWW page server, e.g. Apache HTTP Server, and an application server, e.g. Apache Tomcat to execute servlets. Additionally, users had to install Java Virtual Machine (JVM) to execute applets on the client side. In presented solution the Microsoft SQL Server fulfilled the database server role.

### 3. DESCRIPTION OF TEST DATASET AND ITS PROCESSING

To generate orthophoto image the following data are needed: digital aerial photos, elements of interior and external photos orientation and DTM. The test material included the block of two strips photos. There were six photos in the strip. The aerial photos were taken by an analog Zeiss's LMK 2030 camera in the region of campus of University of Warmia and Mazury in Olsztyn. The scale of photos was 1:8000, with the camera focus equaling approximately 305 mm. Coordinates of principal point and fiducial marks were included in the attached calibration report of the camera. Photos were scanned with the pixel size approximately 21  $\mu$ m.

To determine the transformation from pixel coordinate system to an image coordinate system, affine transformation was used. The coefficients of inverse transformation were calculated too. Additionally, for determination of the external orientation aerotriangulation was performed.

The all data concern photos were stored in the database. According to the structure presented in the figure database contained two tables. Table PHOTO included basis information like numbers of columns, rows and levels of pyramid, and also shown which photos made up stereo-pair. There are elements of photos orientation in the second table, where  $a_{af}, b_{af}, c_{af}, d_{af}, e_{af}, f_{af}, ck, xs, ys$  related to coefficients of affine transformation, whereas  $X0, Y0, Z0, OM, FI, KA$  was the external orientation elements.

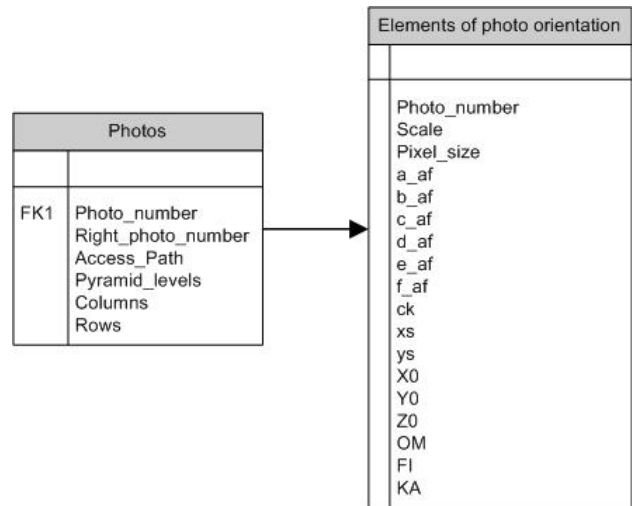


Figure 2. The structure of photos database.

### 4. ALGORITHM OF DTM AND ORTHOIMAGE GENERATION

DTM and orthophoto images a commonly produced by the use of digital photogrammetric workstations that are usually equipped with advanced technology. The process of creating web photogrammetric applications has not been based on copying or translating the source codes of such systems. It was necessary to build new programs to conduct definite tasks. They ought to fill gaps in of the user's existing software and take into consideration the properties of the network structure (Harold 2004).

The algorithm of the web-based approach for online DTM and orthoimage generation is presented with the aid of UML activity diagram in the figure 3. In presented solution there are three successive steps: parameters determination, DTM built and orthoimage generation. In the next part of paper we focus on the problem of DTM construction. The mathematical basis of construction of orthoimage as a function was also described.

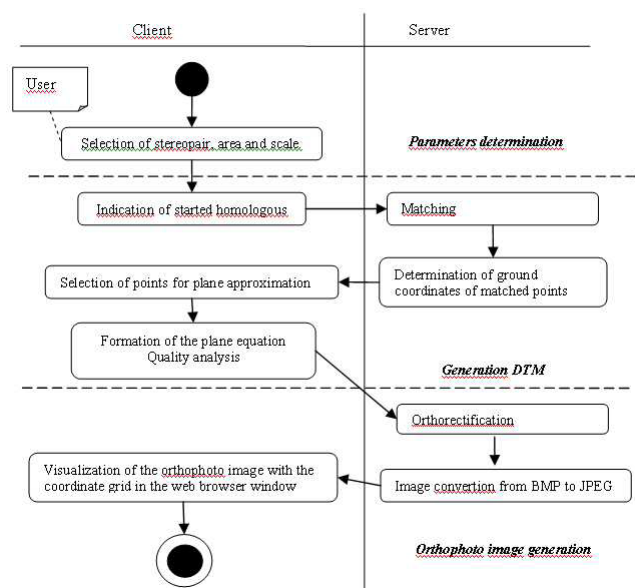


Figure 3. Activity diagram shows steps in the process of online DTM and orthoimage generation

#### 4.1 Digital Terrain Model

DTM is an element that is necessary in the process of creating orthoimages. Aerial photogrammetry provides major source of data that are used to create it. The main task in the photogrammetrical approach is to measure homologous points on two or more images (photos), i.e. selecting an object on one photo and finding its equivalent on the other one. In analogous and analytical photogrammetry, this is achieved by manual measurements performed by an operator. Digital photogrammetry aims to solve this problem automatically. This process is called image matching.

Algorithms for automatic DTM construction from raster data (aerial photographs, satellite imagery) are mainly based on correlation methods. The main measurement of similarity (goal function), while using the image matching method, is a coefficient of correlation. For a defined neighbourhood of one pixel on the left photo (neighbourhood of grid point on the left photo) and the same neighbourhood on the right photo, a coefficient of correlation is repeatedly calculated. The area is considered to be matched for the maximum value of the coefficient and when its value is larger than the threshold value (Paszotta, 2006).

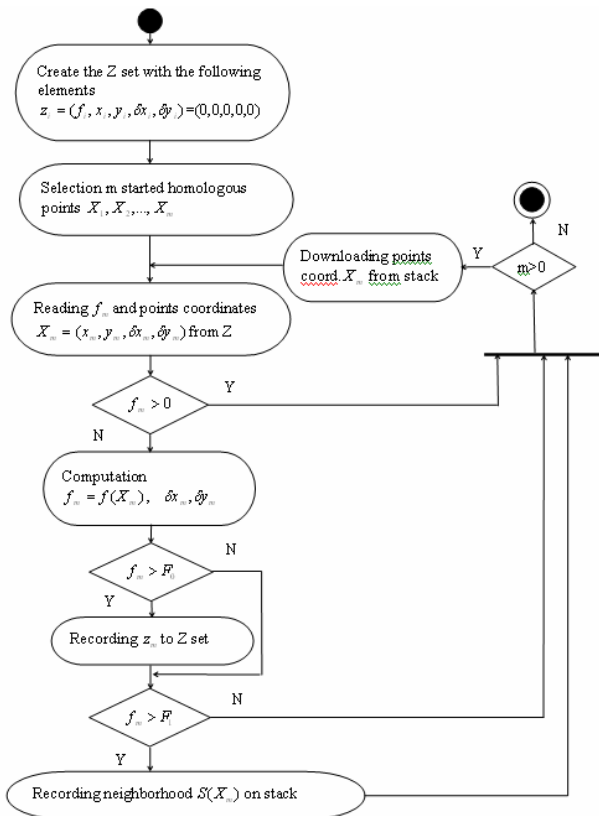


Figure 4. Algorithm of image matching

The diagram of image matching process is shown in the figure 4. We assumed there that the goal function has the form

$$d(c'c'') = 1 - r(c'c'') \quad (1)$$

where

$r(c'c'')$  - correlation coefficient

$c', c''$  - fragments of the left and right photo of stereopair.

The theoretical basis and detailed explanation of mentioned image matching algorithm was presented in other article (Paszotta 2000a)

The above described procedure is repeated on subsequent, previously established grid nodes. Matching results in obtaining a dataset, which includes pixel coordinates of the centres of the areas matched on the left picture, recording the differences between coordinates on the right and on the left picture and the minimum of the goal function (Paszotta, 2000b)

After image coordinates of homologous points have been obtained, data to generate DTM can be acquired in two ways:

- a spatial model is built, by determining elements of reciprocal orientation, which is then transformed to the ground coordinate system.
- after determining the elements of exterior orientation of photos, image coordinates of points measured on the stereogram are directly converted into X,Y,Z coordinates in a ground system, by using collinearity equation.

The last step of DTM generation is modelling of terrain surface. There are many methods of DTM interpolation widely described in the literature of the subject.

#### 4.2 Orthorectification process

The orthophoto image is obtained in the orthorectification process. We defined orthoimage and digital photo as functions  $c'(i', j')$ ,  $c(i, j)$  where arguments of these functions are indexes of pixels (pixel coordinate) and their values belong to the colors space. The colors of orthoimage pixels  $c': (i', j')$  is received on the basis of color pixels of digital photo  $c : (i, j)$ . This relation can be described as the function

$$c': (i', j') \rightarrow c(e(g(f(i', j')))) \quad (2)$$

According to the function 2 the process of orthoimage generation can be shown in the following steps (Paszotta, et al. 2010). The function  $f$  presented the coordinates of the center of the orthoimage pixel in the ground coordinate system.

$$f(i', j') \Rightarrow X, Y \quad (3)$$

The next step was to determine  $Z(X, Y)$  based on Digital Terrain Model.

$$g : (X, Y, Z) \Rightarrow (x, y) \quad (4)$$

The function  $g$  could be described by collinearity equation. It allowed to transform ground coordinates of the point into its digital photo coordinates in the fiducial marks coordinates system.

Then based on the function  $e$  the digital photo coordinates were transformed to digital photo pixel coordinate.

$$e : (x, y) \Rightarrow (i, j) \quad (5)$$

The last step was calculated the color of digital photo pixel used one of the resampling method  $c : (i, j) \Rightarrow c(i, j)$

As a result of the ortorectification process the image that show cartometric view of the Earth's surface is recorded in BMP format.

### 5. THE EXAMPLE OF ONLINE DTM AND ORTHOIMAGE GENERATION

The presented web application has consisted of applets and servlets that was written in the JAVA programming language and has worked on the Department of Photogrammetry and Remote Sensing server <http://www.kfit.uwm.edu.pl/zp1/or.html>. Data that is necessary for constructing orthoimage has been obtained from several sources: parameters of photos orientations from the database, photos and their fragments from a directory of photos on the dataserver, and other data – initial parameters of process of DTM and orthoimage generation have been delivered by the client. The application has started working on the client side after downloading the mentioned above web site. User has had to select the stereopair and appropriate photo pyramid level, indicate the area of interest on the selected photos and send to application server request for preparation of photos fragment. After that the web browser windows looked like in the figure 5.

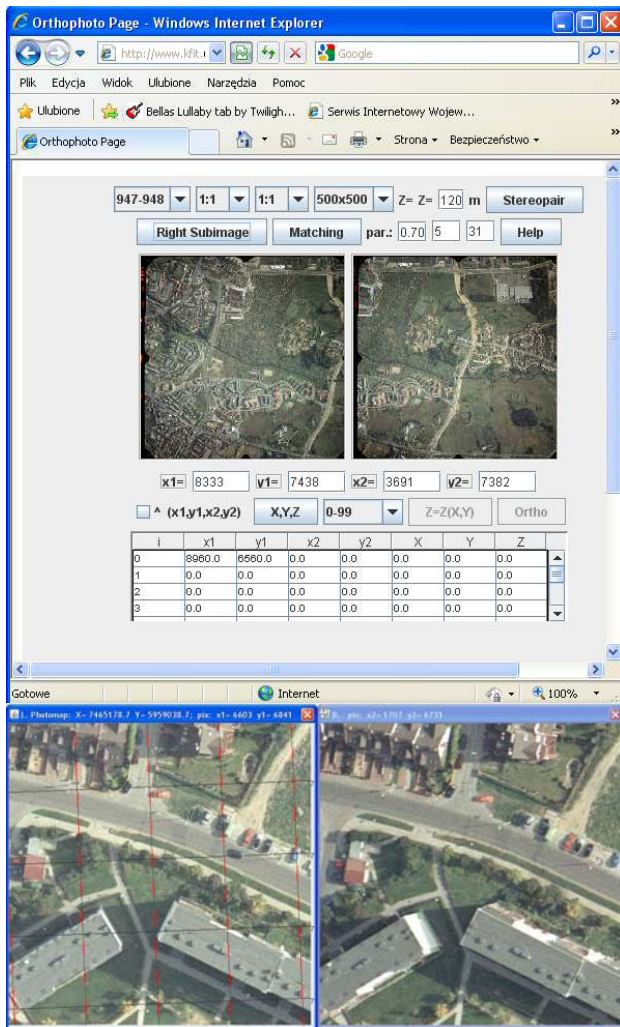


Figure 5. View of the web browser window with the running web application of DTM and orthoimage generation.

The next step is DTM generation. The main task of this stage concentrate on homologous point measurement. The measure of similarity between the digital images is the correlation coefficient. To perform this operation, pixel color values from RBG color space should be transformed to monochromatic color space. The user defines also a threshold for correlation coefficient, the target size (pattern), and step changes in the coordinates (in pixels) on the right photo (size of search window). After selecting a starting point on the left and right photos – identifications of all other conjugate points is performed automatically. The result of this operation is shown in the figure 6. It should be emphasize that the image matching is executed on the original images on the server side. Simultaneously the terrain coordinates of points that were used to create digital terrain model (DTM) were calculated in the automatic way.



Figure 6. Results of image matching shown in the web browser window

Since the area of the orthophotomap is small and limited by dimension of the window of the web browser. Thus, in the process of orthorectification over the Internet we assumed a simplified DTM. The proposed method of digital terrain model is approximated it in the form of the plane.

$$Z = AX + BY + C \tag{6}$$

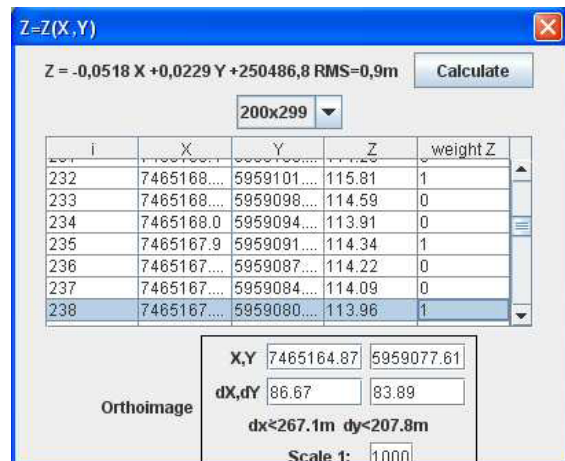


Figure 7. Points selection for plane approximation.

Control point for finding the plane equation coefficients are selected by the user through assignments them the weight equal 1 (figure 7). The coefficients of the plane equation are defined by deploying a least squares adjustment method. Accuracy assessment of the model is also implemented. Conformity between the established model and remaining point was determined by using RMS error. In presented example the RMS is equal 0.9m. (figure 7).

The last stage of our web application is orthorectification process. For the orthoimage generation, user needs to interactively setup the extent of the working area and define a scale of the result, as it is shown in figure 7. As a result of orthorectification process the cartometric image is recorded in BMP format. Additionally the compressed orthoimage is produced in JPEG format and through the applet was automatically forwarded to the client to be displayed in the web browser window. Because of resampling, the created orthoimage has a worse quality than a source photo. Therefore, the source photograph with the system of coordinates is also presented.



Figure 8. Figure placement and numbering

Orthorectification was made on the server side but the grid coordinate system was superimposed on the orthoimage by means of applet on the client side. In both cases the image and ground coordinates of point shown by the cursor are calculated and printed in the header of the Internet browser window.

## 6. CONCLUSIONS

The process of creating orthophoto image together with DTM from aerial photographs is complex and requiring the specialist software on the digital photogrammetric station. However, it turns out that this process with certain limitations can be executed over the Internet. Even, if there is a simplified solution, its advantages are great. This paper presented the algorithm and web application for constructing DTM and orthoimage online. The majority advantage of a such solution is the ability to update and maintain it without distributing and installing software on potentially thousands of client computers.

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