

## DEVELOPMENT OF AN EDUCATIONAL SOFTWARE SYSTEM FOR THE DIGITAL MONO PLOTTING

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### ABSTRACT:

This paper presents a user-friendly Windows-based educational software system for explanation and demonstration of the procedure of digital monoplotting. The software system named Digital Monoplotting Teaching Program (DiMoTeP) is primarily designed to be used by teaching personnel in lectures to bring over this particular topic of photogrammetry to master students in an attractive way. The program consists of two parts: an HTML-based animated tutorial presenting the theoretical background of the method and a practical part demonstrating the procedure with the real data. The theoretical part of the program is a web-based tutorial covering explanation of the topic, i.e. definition and background of monoplotting, required data, methods used in the process and application areas. The demonstration tool is a Windows® software implemented in C/C++ programming language that performs the basic functions of the procedure, i.e. import the DTM and image data, recording the point or line features as well as visualization. The students' feedback showed that the overall structure provides an easy and didactic tool for teaching.

### 1. INTRODUCTION

Learning and teaching by means of modern digital tools is of growing interest in the geomatics community. In the past few years, diverse e-learning environments such as

- <http://www.fpk.tu-berlin.de/wbt/fernerkundung/>: Introduction to Remote Sensing of TU Berlin,
- [http://www.ipi.uni-hannover.de/elan/index\\_main.htm](http://www.ipi.uni-hannover.de/elan/index_main.htm): Course on integrated sensor orientation of Hannover University,
- <http://www.fzg.uni-vechta.de/airlaser/>: Tutorial on airborne laser scanning by University Osnabrück,
- <http://learning.intermaptechnologies.com/>: Tutorial for interferometric SAR by Intermap,
- <http://www.geoinformation.net/>: Multimedia environment for various geomatics topics by several German high schools,
- <http://www.yc.ycc.u-tokai.ac.jp/ns/cholab/RS-fun/>: Introduction to Remote Sensing by Tokai University,
- <http://www.gitta.info/>: Geographic Information Technology Training Alliance, a program of Swiss Virtual Campus

and some others have been set up. These tools are mostly designed as extensive interactive environments to be used for a self-study in addition to traditional geomatics courses. The software presented in this paper follows a different goal. We aimed at developing a *demonstration tool*, which could be used by teaching personnel to explain particular topics of digital photogrammetry in a comprehensive and attractive way. In this paper we show the first results dealing with one of the procedures of the single image photogrammetry, the digital

monoplotting. We plan to extend this work to other topics (model orientation, bundle adjustment, DTM generation etc.) that would represent modules of an "educational digital photogrammetric workstation" focused on the demonstration with real data.

Similar efforts have been presented in Coelho (2004). In this work a comprehensive tool, called E-FOTO, which covers most of the basic steps of the photogrammetric workflow, is given. The tool is basically developed for "self-teaching", which means that the target user group are the students rather than the teaching personnel. Perez-Garcia et al. (2004) have presented two software applications for demonstration of the Hough transformation. Although the tool is designed to assist the educators, there is no explanation material provided in order to teach the theory of the topic.

The project presented in this paper was conducted as a diploma thesis of the first author (Fluehler, 2004) supervised by the second and third authors. As it was the first work of this kind at our chair, all the procedures were developed "from the scratch". The total time available for the literature study, software development, thesis writing and its presentation were 4 months. The result is an easy-to-use Windows-based tool (Figure 1) including the explanation of the method, demonstration using the real data and the software documentation. It is a freeware that can be downloaded from the webpage of the Chair of Photogrammetry and Remote Sensing of the Institute of Geodesy and Photogrammetry, ETH Zurich: <http://www.photogrammetry.ethz.ch/research/student/monoplott ing.html>.

The data comes as an integrated part of the installation file. We use a data set of Ayers Rock in Australia, as this is an impressive object with distinct height differences suitable for

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the purpose of our project. For the demonstration of the digital monoplotting we include an aerial image, an orthoimage and the digital elevation model (DEM). The original resolution of both image files as well as of the DEM was significantly reduced in order to fasten the processing time.

The tool has already been used for a lecture within the post-graduate course at our Institute (next lectures are planned for the running semester). The participants of this course have

various background and mostly do not come from the field of geomatics. Their reactions were overall positive. It was much easier for them to understand this particular photogrammetric topic as the whole procedure was not only theoretically explained but also practically demonstrated. In Section 2 of this paper we describe both the explanation and demonstration tool in detail, followed by the conclusions in Section 3.

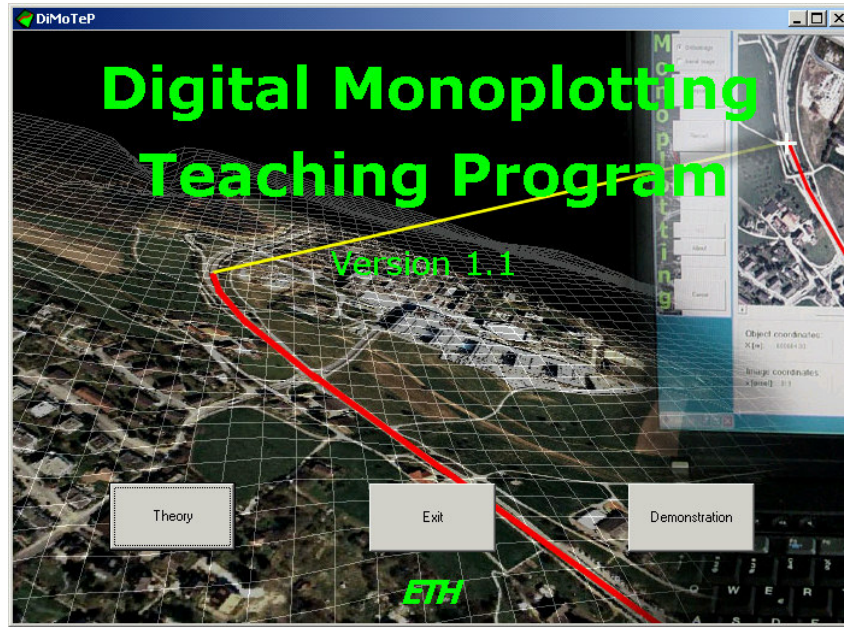


Figure 1. Digital Monoplotting Teaching Program (DiMoTeP).

## 2. DIGITAL MONOPLOTTING

### 2.1 The Explanation Tool

Monoplotting is a procedure of single image photogrammetry for obtaining real-time 3D coordinates from the measurements in image space (Figure 2). The required datasets are a Digital Terrain Model (DTM) and an aerial image with its orientation parameters or a geo-referenced orthoimage respectively. The relevant image features are interactively digitized in the original or orthorectified image. Due to the underlying DTM the 3D coordinates of these features can be computed in real time.

The explanation tool is a web-based tutorial, which is prepared as hyperlinked HTML pages. It has been optimized for Internet Explorer and Netscape Navigator with the resolution of 1024 x 768 pixels. It covers all of the necessary explanation aspects of the topic under the two main titles:

1. Required Data
  - DTM
  - Aerial Image
  - Orthoimage
2. Monoplotting
  - Background
  - Methods
  - Applications

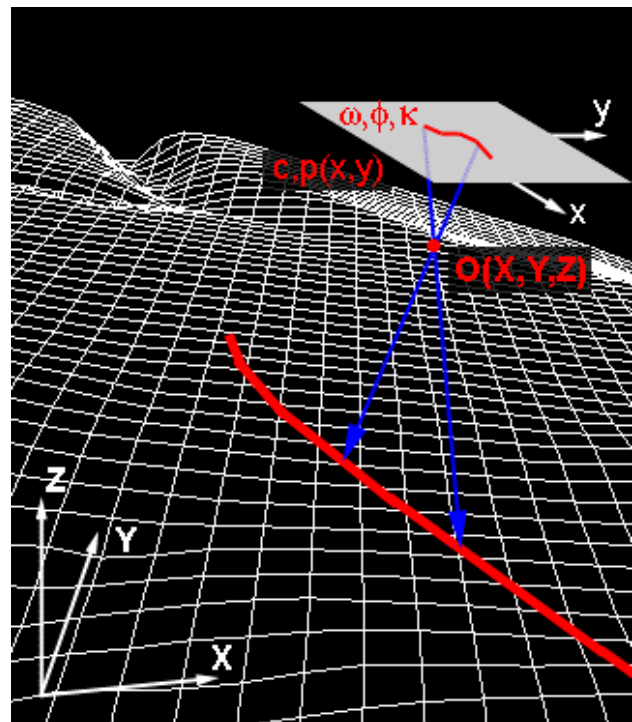


Figure 2. The principle of monoplotting.

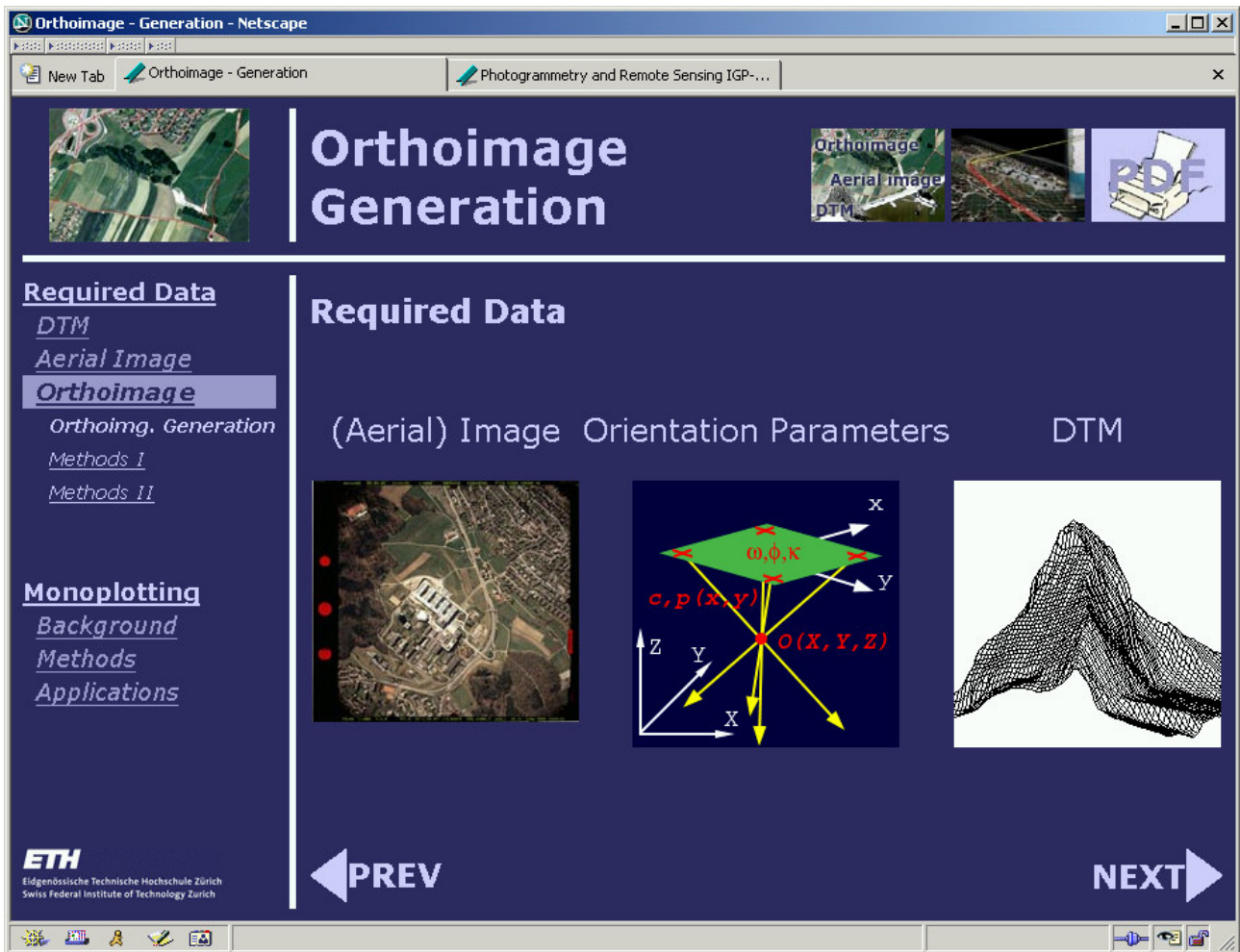


Figure 3. The explanation tool.

### Required Data

Two kinds of data are needed for the monoplotting procedure: a DTM and an overlaying image with its orientation parameters or optionally an orthorectified image. This DiMoTeP part gives an overview information about the input data.

The text content is enhanced by informative images and animations. Particular topics are covered in detail, e.g. DTM file formats, interior and exterior orientation of aerial images, difference between the aerial and orthoimage, and orthoimage generation (Figure 3).

### Monoplotting

This software part starts with the background of the monoplotting procedure and ends up with the possible application areas. The processing methods and implementation aspects are explained in detail.

In case that an orthoimage is available for monoplotting, the procedure is straightforward. The X and Y coordinate values in the object space can be directly derived from the point measurements in the georeferenced orthoimage. In the subsequent step the Z coordinate is interpolated from the underlying DTM for the given XY coordinate pair.

When the image is given in a raw (aerial or terrestrial) form without being resampled to a map projection, an iterative monoplotting procedure is applied. After measurement of image coordinates  $x, y$ , the  $X, Y$  and  $Z$  coordinate values are derived by intersecting the image ray with the DTM. The relation between the image and object space is established via collinearity equations (Figure 4). Starting from maximum elevation ( $Z_0$ ) of the DTM, the backprojected position ( $X_1, Y_1$ ) is calculated. Using this position value, a new elevation value ( $Z_1$ ) is interpolated from the DTM. In the next step a new backprojected position ( $X_2, Y_2$ ) is computed using the latest elevation value, and so on. The iterations are done until the change of coordinate values are negligible. This procedure is called single-ray backprojection (Mikhail et al., 2001).

### 2.2 The Demonstration Tool

The demonstration tool is a Windows® software implemented in C/C++ programming language using C++ Builder™ 5 as the Integrated Development Environment (IDE). When the user clicks the “Demonstration” button in the main menu (Figure 1), the window of the demonstration software is called (leftmost menu in Figure 5). It performs the basic functions of the procedure, i.e. importing the DTM and image data, digitizing the point or line features as well as visualization.



Monoplotting - Orthoimage/Aerial Image - Netscape

Orthoimage/Aerial Image

Required Data

- DTM
- Aerial Image
- Orthoimage

Monoplotting

- Background
- Methods
- Principle
- Orthoimage/Aerial I.
- Applications

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## Orthoimage

X,Y: orthoimage  
Z: interpolated from DTM

## Aerial Image

X,Y,Z: intersection of image ray with DTM  
Image space to object space by collinearity equation

PREV NEXT

Figure 4. Single-ray backprojection.

DiMoTeP - Import Aerial Image

## Aerial Image

Aerial Image [.jpg]  
aerial\_image.jpg

DTM (Raster Grid): DTM Import

Interior Orientation

Camera Constant [mm]: c: 152.023

Image Focal Point [mm]: x: 0.00 y: 0.00

Fiducial Marks [mm]:

	x	y
1:	0.000	111.378
2:	111.351	0.000
3:	0.000	-111.378
4:	-111.351	0.000

Marks in corner

Measure

Exterior Orientation

Position [m]: X: 5438.54 Y: 6910.84 Z: 6024.48

Rotations:  rad  deg  gon

$\omega$ : -0.0227765  $\phi$ : 0.0107757  $\kappa$ : -0.3169867

OK Cancel Help

DiMoTeP - Fiducial Measurement

DiMoTeP - Residuals

Residuals of Fiducial Marks [microns]:

	x	y
1:	9	205
2:	-9	-206
3:	9	207
4:	-9	-206

$\sigma(0)$ : 292

OK Remeasure

Figure 5. Interior orientation of the aerial images.



Figure 6. The record module allows digitizing the point and line features.

The first step of the workflow is the import module. It accepts the DTM data in Arc ASCII Raster format (ESRI DTM definition consisting of a header and elevation values). The image files are accepted in JPG format. When the orthoimage is used, JPG file must come with a complementary JGW file, which contains the georeferencing information, i.e. ground resolution of a pixel along the X and Y directions, rotation angles along the X and Y axes, and X and Y object coordinates of the midpoint of the upper-left pixel.

When the aerial image is used instead of the orthoimage, interior and exterior orientation parameters of the image must be known in advance. These parameters are set to the program. Then, the interior orientation is performed in order to establish the geometric relation between the pixel coordinate system and image coordinate system (Figure 5).

In the record modus, single points or lines can be measured in the image while the 3D object coordinates are displayed in real time. User can select appropriate color for the drawings (Figure 6). Three windows (overview, main and magnifier windows) in different zoom levels allow roaming inside the image quickly.

The DTM with the image data as well as the measured features can be exported in VRML format for the visualization (Figure

7). Elevation values can be exaggerated by a user-defined factor for better visualization. In case of using an aerial image, a corresponding orthoimage is calculated for the overlay with the DTM. The VRML file can be visualized by Internet Explorer, Netscape Navigator or another web browser with an appropriate VRML viewer plug-in, or by a 3D modeling and visualization software, e.g. Geomagic Studio or Deep Exploration.

In any step of the procedure user can access the help file by simply clicking the Help button.

### 3. CONCLUSIONS

In this paper we have shown a user friendly system for the demonstration of the digital monoplotting. Although the software only covers a very small part of photogrammetric procedures, another topics can be implemented in a similar way. As our main focus was the demonstration by teaching personnel, the program contains only fundamental textual information. To support the self-study as well, more detailed explanations would be of advantage.

The used programming environment (C++ Builder™ 5 as IDE) proved to be a suitable tool for the straightforward development



of educational software. The programming as well as the generation of a graphical interface can be done in a user-friendly way. Based on a solid knowledge of the object oriented programming the given task could be fulfilled in time, even though the developer was not yet familiar with this programming environment.

The presented software DiMoTeP was awarded by a silver medal of a CATCON 2004 contest during the XXth ISPRS Congress in Istanbul (Computer Assisted Teaching CONtest, <http://www.isprs.org/catcon/index.htm>). The software is free of charge and can be downloaded from the web page <http://www.photogrammetry.ethz.ch/research/student/monoplotting.html>.

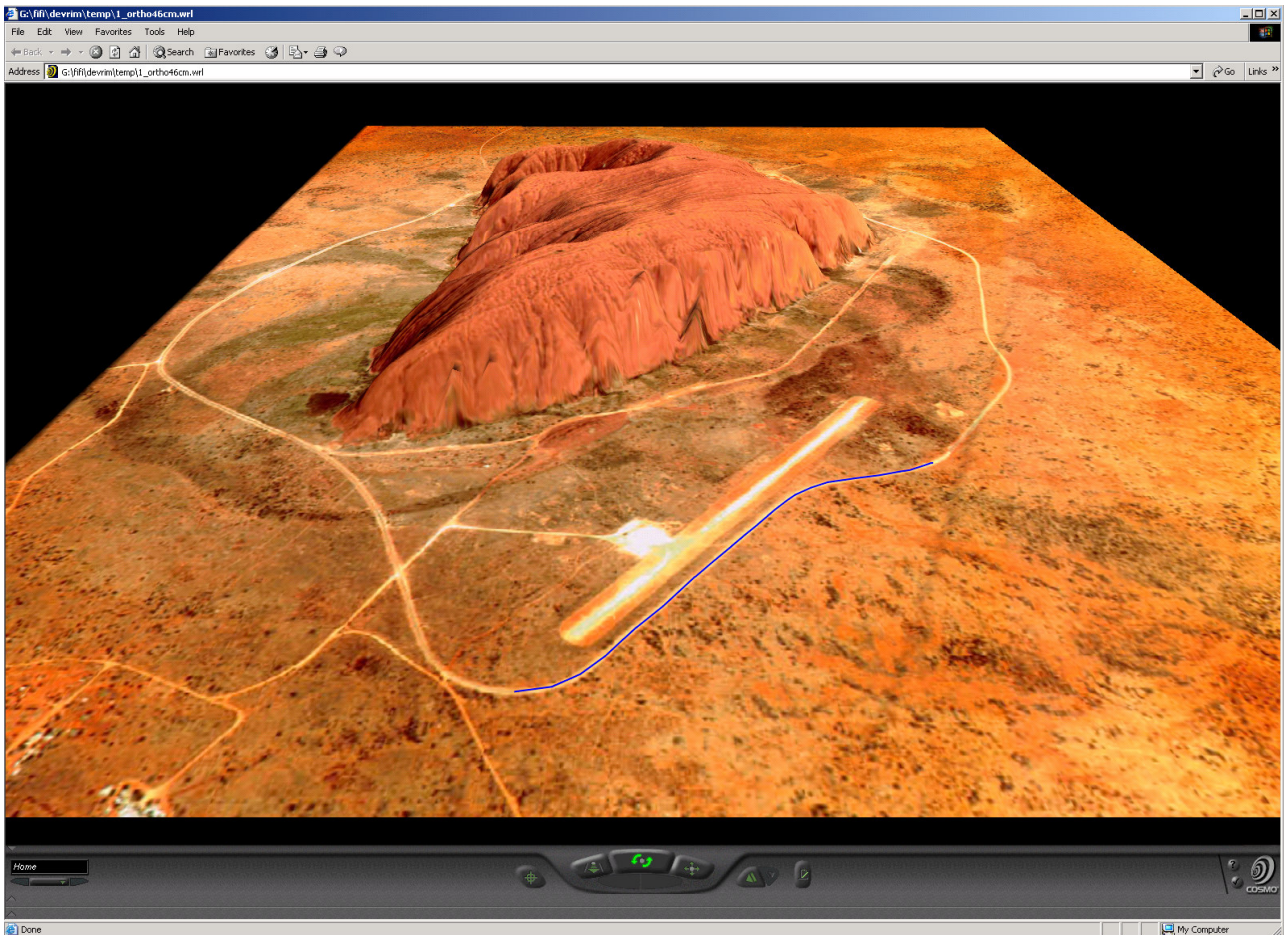


Figure 7. Visualization of the model in VRML format.

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