

# E-FOTO: AN EDUCATIONAL DIGITAL PHOTOGRAMMETRIC WORKSTATION

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## ABSTRACT:

The idea behind the E-FOTO project is to offer a simple set of software and didactic material that could help students understand the principles behind Photogrammetry. The project is based upon two main principles: freedom of use and self-teaching, so, the students can fully understand the principles behind Photogrammetry – reading the e-book, using the software, taking a look at its source code and even modifying it or developing new modules for it. So far, the following modules have been developed: Image rectification, Interior Orientation, Exterior Orientation, Phototriangulation, Stererogram Normalization, Digital Elevation Model, Ortho-rectification and Digital stereo-plotting. There are also, four main documents that are being developed as part of the E-FOTO project: the online help, the e-book on Digital Photogrammetry, the homepage of the project, and the additional text files that contain relevant information on some aspects of E-FOTO. Future trends for the project will be the refining of its documentation, thus turning it available in several languages, and code as well. The evolution of the project will enable the treatment of the set of software as a whole interconnected package, with the exchange of information through XML files with four functionalities: to save, to access, to validate and to process data generated by E-FOTO modules. Finally, it is the team's intent to develop on-demand courses and e-learning environment that will make possible the adaptation of it to University curricula and the creation of extension courses and symposia.

## 1. INTRODUCTION

### 1.1 General Introduction

The E-FOTO project aims the implementation of an educational, digital photogrammetric workstation. Such an implementation follows the GNU/GPL principles for free-software. The E-FOTO was not conceived for competition with the commercial solutions for digital photogrammetry. In the E-FOTO environment the users are able to learn in practice the concepts, tools, and algorithms hidden in a commercial solution of a digital photogrammetric workstation. Besides, source code access freedom turns E-FOTO also useful for researchers around the World, since it can be used in photogrammetric experiments. This goal is achieved by means of a didactic material available at the E-FOTO's home page. ([www.efoto.eng.uerj.br](http://www.efoto.eng.uerj.br)). This didactic material is a set of three digitized-frame, aerial images, the camera calibration certificate in pdf format, and a set of ground control-points. The project presents all of its planned modules working and available for the community, and the current stage of development is related to improvements according to software engineering concepts.

### 1.2 Brief History

The E-FOTO project started in 2002, at the Military Institute of Engineering and achieved the initially planned objectives in May/2007, at the Geomatics Post-Graduation Program at the Rio de Janeiro State University, when the following modules had their first version completed: rectification, interior

orientation, exterior orientation, phototriangulation, digital restitution, stereogram normalization, numeric model extraction and ortho-rectification.

### 1.3 Repercussion and Future Steps

The E-FOTO project and its material have been used by various institutions and individuals, both in Brazil and abroad. Despite performing photogrammetric tasks, E-FOTO does not do that in an integrated way: each module is independent. This is one of the new steps of the project and will be discussed throughout the article.

These new implementations currently involve: (1) the treatment of a XML photogrammetric project control file and (2) a control layer for the project as a whole, with the objective of integrating the project in a sole package, simpler to use.

The control layer will also control all the input and output data flow. This will allow the user to insert only the necessary data for the current module on the XML previously saved file. Another function this control layer will have is the validation of data given by the user through the visual interface.

### 1.4 Objectives

This paper aims at describing the results already obtained by the project, as well as the impact it has provided so far. It also describes steps for the future and trends in the current development of the project.

## 2. METHODOLOGY

### 2.1 Main

The E-FOTO project was most recently developed within the Master's in Systems and Computing Program / Geomatics, at the Rio de Janeiro State University. The development team had a multi-career profile, including in it specialists in photogrammetry, software engineering, webdesign and computer programming: researchers and professors from the Geomatics program but also undergraduate and graduate students (both Cartographic and Computer Engineering ones). Special scholarships were destined to technical and administrative support personnel and funds were directed towards the publishing of the Digital Photogrammetry book and designing of the official webpage.

As for the strategy adopted concerning the development of photogrammetric modules, at first, algorithms were implemented using a high-level language. The MathCAD platform was used at that moment. After tested and implemented in MathCAD, the algorithms were implemented in C++, with the aid of QT Graphic User Interface. The 0.0x versions of E-FOTO were subsequently made available on the Internet, when new functionalities were developed, as can be seen on the project's webpage.

Despite possessing functionalities of a digital photogrammetric workstation, it is important to notice that, because of the difficulty of integrating such functionalities, it was not possible yet to have them connected the same way a digital photogrammetric workstation would have. This is one of the trends for the future, which will be described later.

## 3. RESULTS

### 3.1 Image Rectification Module

According to Andrade (1998), to rectify an image is to project it according to its own perspective axis, on a horizontal plane. This means that, through rectification, it is possible to modify, or even completely eliminate the attitude angles of the camera, related to a certain reference point, as well as the focal distance of the resulting image.

The main objective of rectification for aerial/orbital photogrammetry is to generate a new vertical image without the distortions created by the sensor's attitude while images are taken. There are basically two ways to perform rectification operations: transformations (affine, isogonal, polinomial, projective, etc.) and the colinearity principle. On E-FOTO, image rectification can be done through the transformations: general affine, isogonal affine, orthogonal affine, rigid body affine, isometric and projective. Beyond that, the software allows four pixel interpolation solutions: nearest neighbor, bilinear, bicubic and Lagrange.

The Image Rectification Module started as an undergraduate final project (Lima, 2003), in which image rectification algorithms were implemented and tested on Mathcad. Such project implemented 6 types of transformations: general affine, isogonal, projective, orthogonal, rigid body and direct linear transformation. However, the software used for that is not free and also did not let the user interact directly on the image.

In 2005, the Image rectification module was developed on C language, in order to become more flexible, since it could be attached to an interface, and having the executable program available to the community. This version had as an improvement the implementation of four interpolation algorithms: nearest neighbor, bilinear, bicubic and Lagrange. Figure 1 shows the Image Rectification Module.



Figure 1. Image Rectification Module

### 3.2 Interior Orientation Module

The Interior Orientation module started also as a final project (Coelho, 2002). It was implemented on C++, with the aid of the development tool QT. This version, although using the correct formulas and source code, presented some problems related to its amicability and usability (IBRAU, 2007), since the software was developed in order to prove its proposed concept.

In 2006, with the expertise aquired through the implementation of some E-FOTO modules, as well as its use by engineering students and its community, there was the need to invest more on amicability and usability, since a poorly developed software can turn it difficult to comprehend, and therefore, obsolete. So, E-FOTO's new interfaces were developed in order to turn it more efficient, easy and intuitive, and some parts of its code can be better used by other modules. A good example of that is the "view" class, which is responsible for visualization and measurement of digital photogrammetric images, and that is used by the Interior Orientation, Exterior Orientation, Digital Measurement, Phototriangulation and Normalization modules. Interior Orientation is the transition into this phase. Figure 2 shows the Interior Orientation module.



Figure 2. Interior Orientation Module

When performing the Interior Orientation, the module returns the results and all the matrices involved in the transformation as well. Also, the user can see the statistic parameters of adjustment quality.

### 3.3 Exterior Orientation Module

The Exterior Orientation Module was implemented directly in C. However, it presented the same problem the Interior Orientation one had and it had to be improved. The first version's results were good and its source code was still used while implementing the new one.

As Figure 3 shows, it is possible to see that the user has the option to zoom the image and mark points easily, in order to make a precise measurement. The user's only task is to find and measure points, in this case.

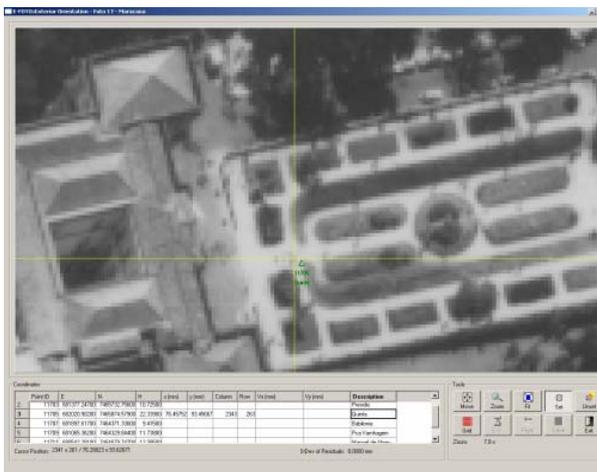


Figure 3. Exterior Orientation Module

Like in Interior Orientation, this module gives the results to the user, and the value of all matrices involved in the transformation, plus the statistical parameters of adjustment quality. It also returns the number of iterations involved in the whole process, or a message telling the adjustment didn't converge.

### 3.4 Phototriangulation

The Phototriangulation module was created as a development of an undergraduate project (Silveira, 2004), which was related to the development of an algorithm for the calculation of point coordinates using bundle adjustment phototriangulation. It was tested with a pair of images, comparing it to existing solutions, and offered good results. However, this initial step was still a MathCAD algorithm, and it was necessary to port it to another language, in order to turn it more user-friendly and computationally powerful.

The code was then converted to C++, and two interfaces were created over it: a point measurement one (where the user can measure a point on-the-fly, obtaining its coordinate) and a photogrammetric points creation one (where the user can define a set of points, like Grubber points for example, and have their coordinates altogether). Figure 4 shows a print-screen of this module.

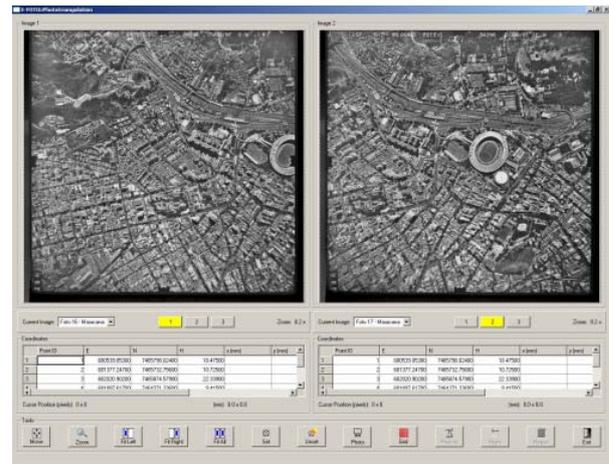


Figure 4. Phototriangulation Module

### 3.5 Stereogram Normalization Module

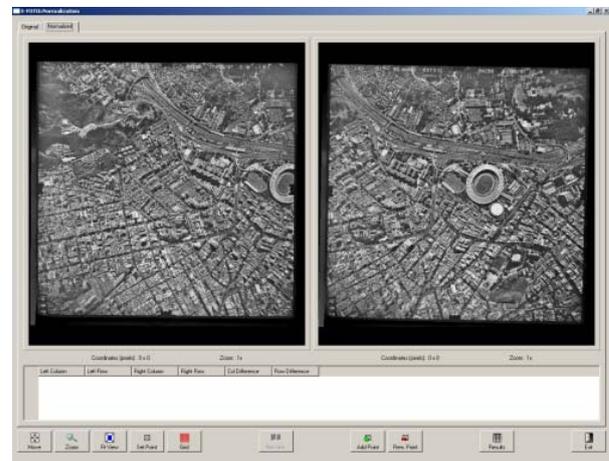


Figure 5. Normalization Module

This software uses Schenck-Cho normalization algorithm (Schenk and Cho, 1992). Normalization aims at generating a new stereogram according to epipolar geometry, turning automatic measurement algorithms more efficient. This software was developed also as an undergraduate final project (Sokal, 2007).

### 3.6 DEM Extraction Model

The Numeric Elevation Model, or Digital Elevation Model (DEM) module intends to allow the creation of a virtual grid on the terrain, so, elevations' values can be determined and a model for this terrain can be built, in order to generate an orthogonal image of it. The software uses the colinearity equation concept, in order to reconstruct perspective rays and measure 3D points on the terrain. It also uses spatial intersection, which recreates the same stereoscopic model analytic aviographs generate for measuring elevations.

A test was performed, using images of the Rio de Janeiro State University's main campus, generating a 3D visualization of it. Figure 6 shows the DEM module.



Figure 6. DEM Module

### 3.7 Ortho-Rectification Module

The Ortho-Rectification module was implemented together with the DEM Extraction module, as a subsequent process to the extraction of a numeric elevation module. Once this module is extracted, the resulting ortho-image can be generated in two file types: the first one contains the whole model, with information regarding elevation and grey levels and the second one, containing only grey level information, i.e. a digital orthoimage.

### 3.8 Digital Restitution Module



Figure 7. Digital Restitution Module

The Digital Restitution module has the objective of generating surface contours of objects that can be found on a pair of digital photogrammetric images. With such contours, it is possible to determine tri-dimensionally features and objects which can be inserted as break-lines on numeric elevation models. Figure 7 shows the Digital Restitution Module.

### 3.9 Educational and Online Tools

The following four documents are being developed as part of the E-FOTO project: the online help, the e-book on Digital Photogrammetry, the homepage of the project, and the additional text files that contain relevant information on some aspects of E-FOTO.

## 4. TRENDS FOR THE FUTURE

Future trends for the project will be the refining of its documentation, thus turning it available in several languages, and code as well.

### 4.1 Code Re-Engineering

Despite providing photogrammetric functionalities, E-FOTO does it in an independent approach, which means that there is not an integrated environment, but stand-alone applications. The evolution of the project will enable the treatment of the set of software as a whole interconnected package, with the exchange of information through XML files with four functionalities: to save, to access, to validate and to process data generated by E-FOTO modules. A control layer will help manage the interaction between the user and the software.

Also, a software's life-cycle is not over when the executable files are released. On the contrary: this is the beginning of one of the most important tasks: code maintenance.

So, the E-FOTO project is trying to correct bugs (and other small problems related to the source code) of its old software, while new versions are developed. There are online tools (e-mail and SourceForge forums) that allow users to report such problems to the development team.

Since the beginning of the E-FOTO, the multiplatform QT graphic user interface was used. This interface allows the software to be compiled in Windows, Linux and MacOS. The current version of it is the 4.0. Each major QT migration demands heavy work on updating code, since several classes are deprecated. E-FOTO was updated already to QT 4.0.

### 4.2 E-Learning

Finally, it is the team's intent to develop on-demand courses and e-learning environment that will make possible the adaptation of it to University curricula and the creation of extension courses and symposia.

The main idea is to use the interactivity allowed by the Internet, experimenting with tools such as websites, virtual classrooms, chat, e-mail, forums, digital libraries, etc.

The main pedagogical benefits behind such educational systems are (Pimentel and Santos, 2002):

- Interactive knowledge (without classroom time limit);
- The student can study anywhere, and following his/her own rhythm;
- Students can collaborate among themselves and with their professors/tutors;
- Network navigation, allowing search for own answers;
- Modularity of subjects, allowing the student to access content following to his/her natural learning style.

Another possible evolution for the project is the translation of the Digital Photogrammetry book (and related e-book) into English and Spanish. Volunteers are needed for both, however.

## 5. CONCLUSION

As a final word, it is possible to say that the E-FOTO project has been trying to help the environment that has been supporting it: a "third world" country university, where budget and funding are always delicate issues. However, it is now

possible to have the necessary continuity upon the research infra-structure developed by the project.

The continuous development and a new life cycle of the software, didactic material and project webpage might allow in the future several further developments which will, for sure, contribute for the growth of this project.

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