

3D PHOTOGRAMMETRIC RECORDING USING DLT AND CAD

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ABSTRACT:

Novice users currently use Digital Photogrammetric Applications increasingly in order to record close range objects of great cultural value or for the monitoring of sensitive objects or procedures (industrial and medical applications). Monoscopic procedures (digital rectification) have been embedded recently, in many popular commercial applications. Also, CAD and CAM applications are gaining even more their use by people of low knowledge background in Photogrammetry, namely Archaeologists, Medical Doctors, Mechanical Engineers, etc. 3D photogrammetric applications are very important and could be part of the every day activity by the above-mentioned professionals. Since the real world is 3D and the demand for accurate recording and representation is increasing even more with the development of new high tech computing systems and reproduction devices, the development of easy to use 3D photogrammetric software applications is more than ever a necessity. Ground Control Points (GCP) measurements, bundle adjustment of collinearity equations and camera calibration procedures applied to stereoscopic and convergent photogrammetric images offer the most efficient and accurate solution. However, the above-mentioned tasks are hard to be applied by many potential users with low implication in photogrammetric projects. There are also some cases where these tasks cannot be applied due to the uncertainty or short of information about basic camera calibration parameters. In these cases, Direct Linear Transformation offers a way to extract reliable 3D information with just the use of some GCPs which could be easily measured using modern conventional reflectorless Total Stations. This paper is describing our attempt to provide a low cost CAD software application embedding the DLT photogrammetric processing to create accurate 3D drawings of close range objects. The use and distribution of the application is free for academics while the demands in hardware configuration (CPU and graphics card) are very low.

1. INTRODUCTION

The use of DLT (Direct Linear Transformation) in order to calculate the object space of imaged objects has given very good results in the past (Douglas, et.al. 2002, Savapol and Armenakis 1998, Remondino, 2002). It is a very well documented process that has the ability to provide, in a sort time and with adequate accuracy the 3D information of imaged details on an object ignoring the physical mathematic model of the central projection. It embeds parameters to model not only the extrinsic but also the intrinsic camera values. Even most important is the use of parameters that describe the most significant camera calibration parameters such as the radial distortion and the camera constant value, in the DLT equation model (Tsai, 1987, Dermanis, 1991).

The sensor to be used in the DLT process can be any off-the-shelf imaging device such as a typical dSLR camera with a camera lens of low radial distortion values or any low-cost (but of lens with high values in radial distortion) compact digital camera. In a typical bundle adjustment procedure using the collinearity equation model, the imaging sensors should be only of one kind in order to provide the most accurate results. Even different camera constants of the same sensor might increase the processing complexity and decrease the overall precision. After all, in a typical photogrammetric project a single camera is used to provide the projects images. Thus, most of the commercial photogrammetric applications solve projects of images coming from a single camera.

In the case of DLT there is no limitation of the types and number of sensors that will be used to record an object and the computation of parameters describing the intrinsic camera values is unique for every image. Consequently, higher accuracy is expected from the DLT solution in a typical Single Camera/Multi Image photogrammetric project.

2. MATHEMATIC MODEL

The DLT equations model consists of the following unknowns and observations

$$\begin{aligned} f(x, X, Y, Z, L_1, L_2, L_3, L_4, L_9, L_{10}, L_{11}) &= 0 \\ \Leftrightarrow x - \frac{L_1 \cdot X + L_2 \cdot Y + L_3 \cdot Z + L_4}{L_9 \cdot X + L_{10} \cdot Y + L_{11} \cdot Z + 1} &= 0 \quad (1) \\ g(y, X, Y, Z, L_5, L_6, L_7, L_8, L_9, L_{10}, L_{11}) &= 0 \\ \Leftrightarrow y - \frac{L_5 \cdot X + L_6 \cdot Y + L_7 \cdot Z + L_8}{L_9 \cdot X + L_{10} \cdot Y + L_{11} \cdot Z + 1} &= 0 \quad (1) \end{aligned}$$

where x, y are the image coordinates of the control and tie points on the images and X, Y, Z are their 3D coordinates. The unknown parameters are the L1, .. L11 values. The unknown

values do not have any obvious physical meaning in the solution. However, they can be connected mathematically to either the exterior or the interior orientation parameters of an image. The model can be extended to include also parameters that model the camera lens deformation of the images through a calibration process (Seedahmed and Habib, 2002).

In our approach we have provided a solution model of least square adjustment using the equations (1). Within a single processing step both the unknown DLT parameters and the 3D coordinates of tie points are calculated, using the observation equation model. There is, also, the ability to perform a forward resection to calculate the 3D ground coordinates of every point depicted in at least two overlapping images using the already pre-calculated parameters L_1, \dots, L_{11} . Multiple image processing can also be achieved increasing the accuracy of the calculated 3D coordinates of the imaged points.

3. IMAGE PROCESSING AND DIGITISATION

3.1 IMAGE PROCESSING

The images used to provide the 3D coordinates using our approach can be any scanned photographs or digital files derived from a digital metric or non-metric cameras. Since the solution model consists of only 11 unknown parameters of no obvious physical meaning there is no need to perform the interior orientation for any image. Also, in the case where the images are created by digital cameras, the constant value (f) stored in the EXIF image file, can be used to provide the relative orientation of a set of overlapping images, along with a typical size of the camera's sensor, (Figure 1). In this case, although the DLT model is used for the space resection and calculation of the 3D coordinates of conjugate points, the epipolar lines can be projected on the images to make their collection easier.

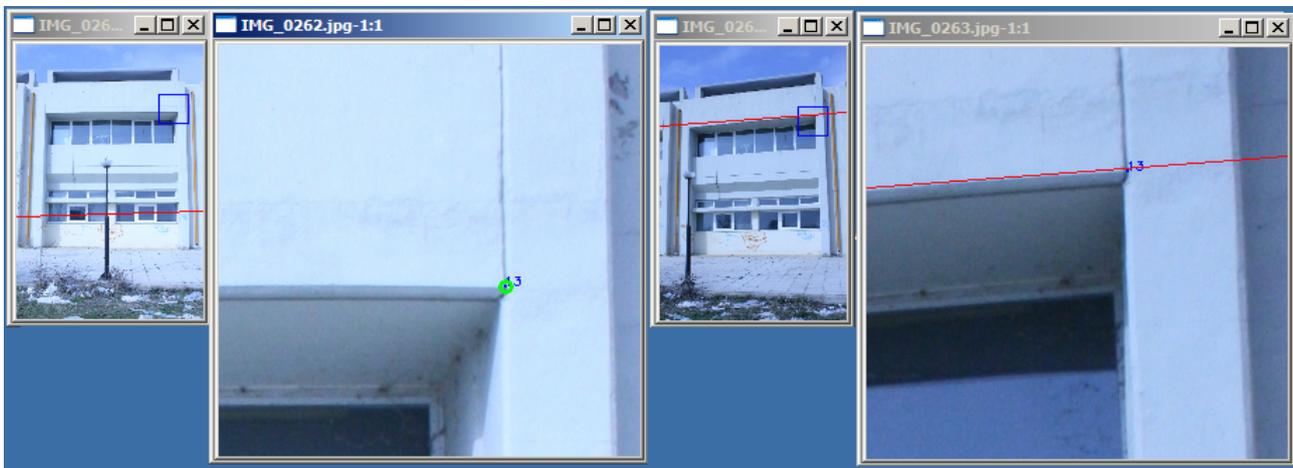


Figure 1. Epipolar lines help the collection of conjugate points

For every image included in a project file, two windows are used to provide an overview and 1:1 scale images (Figure 1). The overview window is used to navigate along the image and concentrate on any of its region of interest (ROI) in the 1:1 scale window. A set of three images can be viewed and processed simultaneously for ground control and tie points collection and for the 3D digitization of the object's features. However, a single project file can hold up to 20 images. The visible images to be processed can be any of the images stored in the project file. The user can select which images will be viewed and processed simultaneously.

A control dialog box window displays the project information and through its command buttons all the photogrammetric processing is performed (Figure 2).

An Open Source image processing library has been used for the manipulation of the digital images. OpenCV (Copyright © 2000, Intel Corporation) is a widely spread library that includes almost every image processing function that might be used for photogrammetric purposes. One of the greatest advantages of the software is its optimization to perform in real time applications.

3.2 DIGITIZING

For the Architectural Recording of Cultural Heritage buildings and sites, detailed maps and drawings of the top views, facades' and sections' views, in large scale should be generated. In order to record the building facades, the digital rectification procedure can be used to provide high precision representations in 2D drawings (Tsioukas, 2007). However, in the case where the facade has a variety of vertical planar and non-planar surfaces or when the facade is quite irregular, 3D restitution has to be applied. Many commercial standalone software applications have been created towards those needs and directions (Photomodeler by EOS Systems Inc., ImageModeler by Realviz, LPS by Leica, iWitness by De Chant Consulting Services). All of the above-mentioned applications have the ability to provide, as additional export products, the 3D model of the recorded buildings in 3D DXF format which is the most commonly used file format to provide the details of a building's facade, in digital form. Very few applications are functioning, as plug-in applications, within a CAD environment and some of them are using special 3D visualization configurations to store the 3D model in a CAD file, in real time.

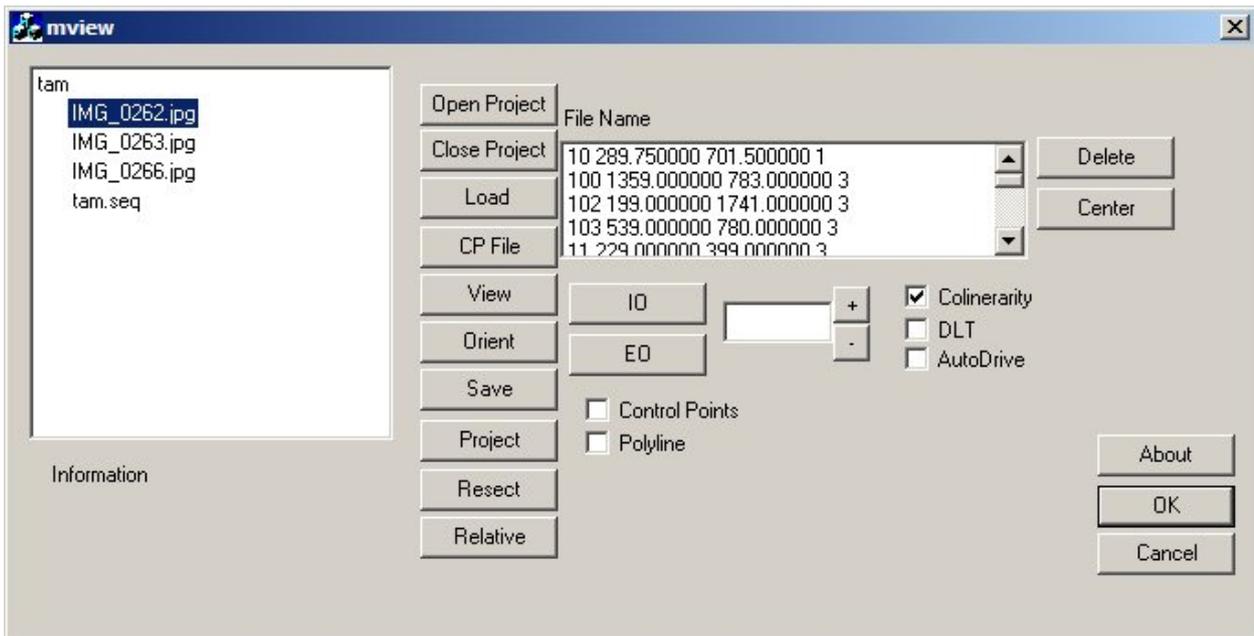


Figure 2. Controlling Dialog Box.

In both cases, of the standalone and plug-in photogrammetric applications, a CAD environment is demanded to provide the final printed result of the 2D drawings. Even if the photogrammetric software cost is low, the presence of a CAD environment is rapidly increasing the overall cost of the recording software.

In our approach we have embedded some minimal 3D vectorising algorithms in our DLT application in order to provide 3D polylines of features on the buildings' facades (Figure 3). The DLT forward resection procedure is then used to calculate the 3D coordinates of the most characteristic points on the images, in object space. All the features are stored in a

vector file that will be finally processed within the VeCAD software application (Tsioukas, 2007).

A modified version of VeCAD has been used to cooperate with the DLT software application and to provide further processing on the vector features of a photogrammetric project.

The execution of the DLT Software tool can be also performed through a toolbar command of VeCAD. Exchange of data sets (Control Points' Files, Images, etc) is a typical process between the two applications.

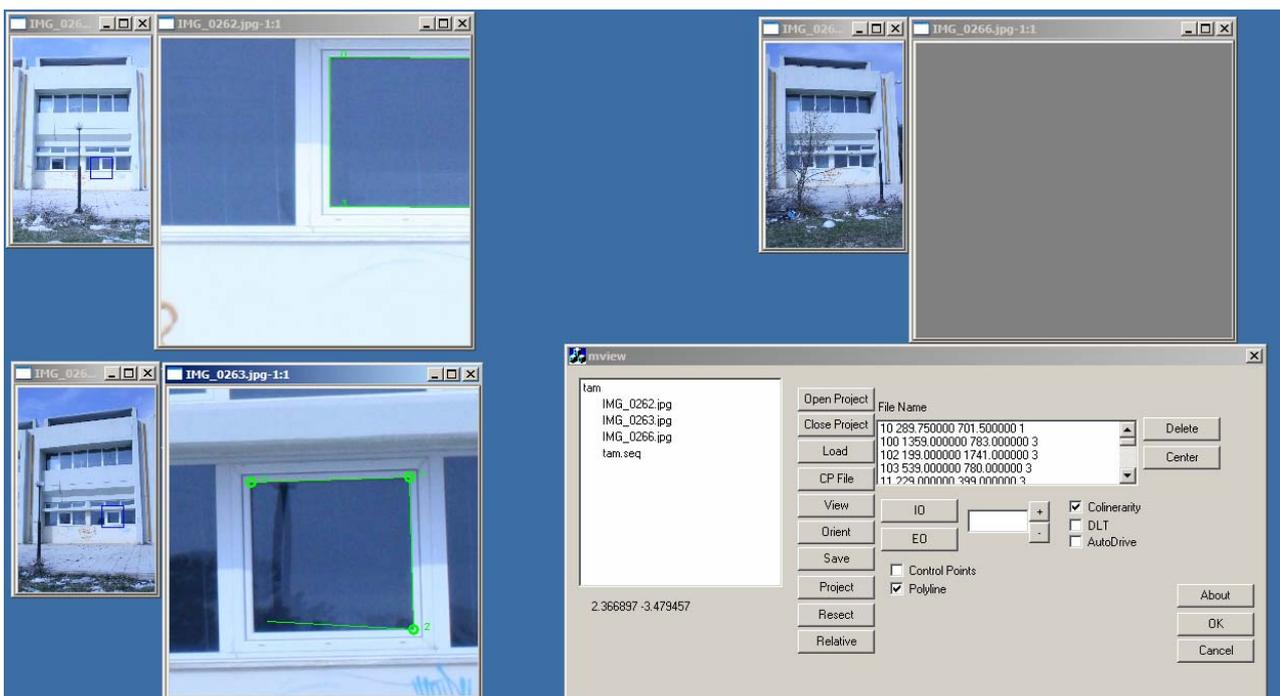


Figure 3. Digitization process.

4. FUTURE RESEARCH

In the next version of our application a more qualified DLT implementation will be implemented and included in the graphical environment, supporting also calibration features.

The software originally was designed for architectural documentation purposes. However, it could be used for the documentation of many other objects like industrial items and archaeological sites. Certain customization should be set for each separate case. For example, the production of a typical orthophoto is not always applicable in an architectural project, while it would be very useful in the case of archaeological site documentation. We plan to provide in the near future different versions of the software equipped with the most suitable features and tools depending on its usage.

5. CONCLUSIONS

One of our primary intentions was the creation of a set of tools that will be user friendly and available to everyone who is willing to use photogrammetry to record architectural details using multiple overlapping images.

In this paper, we present an application that is using DLT to provide the documentation and digitization of buildings facades. Additionally, we provide a cooperating CAD application that is able to perform and finalize the preparation of drawings and printouts.

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