# AN INVENTED APPROACH IN IMAGE REGISTRATION "NEW ERA IN PHOTOGRAMMETRY"

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**ABSTRACT:**

This paper will discuss an invented approach which focuses on providing an output from registration of an aerial photograph on a 3D model such as DTM, DMS, or 3D model. The approach has been developed in order to omit distortions from output and to increase the reliability. In contrast of other image registration methods which their outputs are an image, this approach provide a 3D model which can be used for mapping, visualising, 3D GIS, ortho rectify image. The approach is able to register a mono image on DEM, DTM, DMS, or 3D model with the minimum requirement to camera calibration parameters. The paper will give a discussion on analysis of registration of an aerial image on laser scanning data and registration of a terrestrial image on a 3D model by using this approach.

## 1. INTRODUCTION

Photogrammetry since its emergence has had at least two major transitions. The first transition was begun at late 60s or early 70s when analytical stereoplotters were come into the market and edged out analogue stereoplotters. The second transition was started at mid 90s or late 90s when digital photogrammetry was emerged and gradually pushed analytical stereoplotters out. In digital photogrammetry system a simulated stereoplotter digitally created in the computer and all processing have been implemented digitally, but the mathematical concepts are the same. Consequently, all processes in digital photogrammetry were computerised and a supplementary image processing package was integrated to the system. However, before emergence of digital photogrammetry, digital images, digital image processing, and digital image transformation were successfully implemented in remote sensing and in digital close range photogrammetry as well.

For ascertaining a reliable photogrammetric output, enormous studies on photos, cameras, and mathematical modelling have been fulfilled. With a glance research on all studies, it will be recognised that all those studies, despite of in which period they have been fulfilled, have focused on the determination of interior parameters. For example, Hallert (1968) and Hakkarainen and Rosenbruch (1982) measured angles of rays with help of a theodolite and collimator for defining the focal length. Brown (1956) developed analytical camera calibration, and Brown (1966) mathematically modelled the decentring distortion. Kenefick et al (1972) developed an analytical camera self-calibration with eight physical parameters. Fraser (1997) explained parameters and mathematical model for digital camera self-calibration. Amiri Parian and Gruen (2010) developed a method of self-calibration for panoramic camera.

Photogrammetry has embraced of a number of physics' laws and it needs to fully familiar with them for calibration. Investigation on these physical rules is not the scope of this paper. More details regarding to above issues can be found in photogrammetry and remote sensing textbook, for example Slama (1980) and Lillesand and Kiefer (1987). Photogrammetry during its evolution has tested and implemented different approaches for coping with these issues and producing a reliable and precise output.

This paper will give a report on implementation of the developed approach in two different projects. The first project focused on registering an aerial image on a laser scanning data and the second project registered a terrestrial image on a 3D model.

This paper has been organised as follows. A brief investigation on data fusion and the proposal of data fusion for this project will be given in chapter 2. Chapter 3 will explain the study area. Chapter 4 will describe and evaluate tests and outputs. A conclusion and remarks will be given in chapter 5.

## 2. DATA FUSION AND ITS APPLICATION IN PHOTOGRAMMETRY

In photogrammetry, data fusion is a technique of image processing for combining two or multi images which were acquired from an object in different times or from different locations for achieving accurate output. Data fusion generally is carried out for change detection, updating existing maps, or ortho image production. There are generally three groups of data fusion: image to map, image to image, and image to database registration. Morgado and Dowman (1997) carried out an image to map registration for automatic absolute orientation. Derenyi (1996) implemented map to image and image to map registration for investigation on change detection and Bouziani et al (2010) carried out image to map registration for change detection. Khoshelham et al (2010) utilised image to image registration for change detection, and Suveg and Vosselman (2004) combined aerial photographs with GIS database for extracting building form aerial images.

Integrating an image with a laser scanning data is another technique in photogrammetry for producing ortho-image or ortho-rectify-image. Laser scanners are able to provide a fair accurate topographic data along intensity values from surface of objects that the data can be used for DTM generation and 3D model. There are various approaches and techniques for integrating images and laser scanning data. For example, Iwashita et al (2007) integrated a grey scale image on a 3D model which was obtained from a laser scanner using fast marching algorithm, or Zhao and Popescu (2009) assessed map leaf area index by investigation the integration of Quickbird image and Lidar data, or Mizowaki et al (2002) registered a CT image on MRS image for developing a method of treatment for prostate cancer. Obviously, there are numerous studies on registration of an image on a scanner data for enhancing the image for extracting an object or producing a map precisely and accurately.

In conventional method of image registration despite of which mathematical model would be utilised, an image which was a two dimensional plane would be finally transferred to another two dimensional plane. The main aspiration of image registration is to convert an image to a map or it is better to say to convert a perspective projection to an orthographic projection. Since the emergence of digital image in photogrammetry, enormous approaches on image transformation have been developed and demand on ortho-image has been significantly raised. The benefit of using digital image over conventional film base photos is the flexibility of digital image. Digital images can be easily stretched, squeezed, rotated, radiometric and geometric editing, etc. But it has to be always remember that the output of an image processing is a two dimensional image. There are not any defined approaches for omitting or reducing the distortion from final output. The existing approaches transfer whole of an image according to a mathematical modelling which its components are a matrix of rotation (**R**), translation vector (**V**), and scale factor (**s**). It requires at least four control points for obtaining the elements of **R**, **V**, **s**, if **R** is a 3x3 matrix and **V** has three components.

The proposal for this project is based on developing a novel approach in order to register aerial images on laser scanning data without pre-knowledge about interior parameters and providing a robust and reliable output which is free from any distortion. Then the approach has been extended for registering terrestrial image on a 3D model. The approach can be easily expanded to register any images to any data such as DTM, DMS, Digital Topographic data, and GIS data. According to the proposal, images have been initially divided to sub area according to geometry of object and topography of terrain. Then each sub area will transferred to the host or source data pixel by pixel. During transformation, pixels are converted to points which their elements includes geometric coordinates and intensity values.

Usually a correlation method has been implemented for matching between two or multi images which were acquired by similar sensor from an object. Hence, the camera sensor and laser scanning sensor are different a new approach has been developed for matching between the image and laser scanning data and 3D model. The laser scanners are acquiring data from surface of object and provided those data in point clouds format; however, a digital image is two dimensional format consists of pixels and rasters which included intensity values.

The existing correlation matching for sequence images has been developed based on comparison between the gradients of intensity values of a pixel with its neighbouring pixel on images. Correlation matching has been recognised as template matching, cross-correlation, and convolution. In contrast, scanning matching approaches for matching laser scanning data have been developed based on presentation of location of points in the 2D or 3D space and included point to point matching e.g. Iterative Closest Point (ICP), or feature based matching, or point to feature matching.

In this study the matching between an image and data scanner data has been proposed as following:

1. The image will be initially oriented with the laser scanning data according to provided GCPs. In this step the rotation angle around Z axis "κ" is only rotation angle which is considered for further processing,
2. Equation 1 defining the relationship between the laser scanning data and image according to parameters of orientation will be constructed,
3. The interested features will be extracted from image and will be transformed to laser scanning space according to Equation 1 for matching with their correspondences features.
4. Final transformation

For implementation of above steps correctly, a special filter has been developed that extract the plane from laser scanning data. The filter will remove scattered points that interferes the matching process. For example, each laser scanner pulse signal has three responds from trees and bushes. These additional data affect the process of the matching and transformation and reduce the accuracy of outputs.

$$\begin{bmatrix} x_t \\ y_t \\ z_t \end{bmatrix} = \begin{bmatrix} x_s \\ y_s \\ z_s \end{bmatrix} + sR_\kappa \begin{bmatrix} x_i \\ y_i \\ z_i \end{bmatrix} \quad (1)$$

## 3. STUDY AREA

Test area for registering aerial image on laser scanning data locates in Espoonlahti (approximately 60° 8'N, 24° 38'E) in southern part of Finland. The area can be characterized as low residential urban area having mainly terrace houses and detached houses with a multistorey buildings and apartments in some areas.

Also the most required and applicable data were provided by EuroSDR as well as photographs orientation parameters and GCPs.

GCPs have been measured using real time kinematic (RTK) GPS and some of GCPs represent on cornices of roofs.
Laser Scanning images were acquired with Optech ALTM 3100 and Leica ALS50-II scanners at 2005 and 2007. Technical details of imagery systems and camera are presented below.

**Optech ALTM 3100**
Scanning angle 24 degrees, 20 degrees is processed (±10°)
PRF 100 kHz
Scanning frequency 67 Hz
Flying speed 75 m/s
**Leica ALS50-II**
Scanning angle 40 degrees (±20°)
PRF 148 kHz
Scanning frequency 42.5 Hz
Flying speed 72 m/s
**DMC Photogrammetric Images**

| | |
|---|---|
| Pixel depth | 16 bit |
| Size | 13824x7680 |
| Ground resolution | 5 cm |
| Forward overlap | 60% |
| Side Overlap | 20% |

**Interior Orientation**
Focal length: 120.0000 mm (10000 pixels)
Principle point (differences from the image centre):
Px=0.000 mm
Py=0.000 mm
Pixel size: 0.012 mm
Image size: 13824x7680 pixels (165.888x92.16 mm)

The terrestrial images and 3D data have been acquired from an ancient site in south of IRAN near city of Shiraz. The site's name is Naqsh-e Rostam which includes a number of rock carvings, Graves, and a building named Ka'ba-ye Zartosht. The images and 3D model were acquired from Ka'ba-ye Zartosht which most of photos were acquired from a non-metric camera.

## 4. IMPLEMENTATION AND EVALUATION

For implementation and evaluation of the proposed approach, the aerial image and terrestrial images have been split to small area according to geometry of objects. For example all buildings on the aerial image have been extracted and separated from the image. For terrestrial images, all windows and the door have been extracted and separated. Then according to Equation (1), matching between each extracted object and 3D model or laser scanning data has been implemented. Some objects such as multi stories buildings have a significant depth of view and that side wall with windows can be easily recognised.

Topography of area around Ka'ba-ye Zartosht has set a difficulty for stereo image acquiring. The building has been constructed by stones and has 13.5m high and only by a convergence photography can acquire whole of each wall. It was one of the challenging job to compile data of each wall in a map and GIS. At first it was tried by using a **Zeiss** Stereoplotter PLANICOMP **P33** and a digital photogrammetric system to compile data on a map, but both systems failed to provide an accurate map. Then, it was planned to obtain the 3D data by precise engineering surveying approach. A precise 3D model has been provided with less than 1mm STD. This 3D model has provided precise information for analysing the output from registering the image on the 3D model. It needs to mention that the photos were acquired by a non-metric film based camera. Then photos have been scanned by a very basic scanner. The images have a very poor quality and mostly blurred.

Terrestrial images and aerial images have had some distortions as well as relief displacement which can be easily recognised. In aerial images, facets of buildings can be seen, and even details of facets can be recognised.

Both Leica ALS50-II and Optech ALTM 3100 data were individually captured in a CAD system, and 3D model of building has been reconstructed on the CAD system. The area on the image was divided to sub areas according to geometry of object and topography of. Each sub area individually was transferred on the corresponding area on 3D models pixel by pixel. Before transferring sub areas, an initial transformation of whole image has been implemented. The initial transformation was a rotation around principal distance (**κ**) for a rough orientation of the image with 3D models. For continuing the transformation process of each sub area two points on the image along their corresponding points on 3D models were acquired. Then the program will transferred each individual pixel from the sub area to its corresponding point in the 3D model and the output is a point cloud which has image characteristics. The effect of relief displacement on the image has been removed during transformation. The output shows blank areas which they are scars of relief displacement on the image. Because tall buildings are obstacles the areas behind them, after image rectifying those areas have been remained blank. For filling those blank areas, it is possible to utilise other images has been captured from those areas.

A program has been developed for implementing the process. The program will define a number of windows around the sub areas on the image and their corresponding areas in 3D models. The sizes of windows are varying according to the size of sub area. After matching process has been fulfilled and sub areas on the image and 3D model have been matched according to Equation 1, then pixels of the area on the image will be transferred to 3D models. A note has to be given here that laser scanning data won't precisely locate the corners and edges of building because pulse signals won't precisely hit corners and edges of buildings and each point cloud definitely includes a tolerance errors at X, Y, and Z. And obviously a building will be shrunk in a laser scanning data and its shape will be changed from a rectangle to a non regular four sides shape. For omitting this error, at least three control points on each building are required but it is not feasible because an enormous control points are required a terrain. As small area has been transformed each time, therefore; each area can be corrected individually and also each point can be corrected individually. In image, there is no chance to geometry correct each sub area or a pixel, because all pixels stick together and any geometry changing on any sub area or any pixel will be distorted other areas and pixels. An important notice has to be given here that points are not geometry connected to each other and they can be corrected individually. Another important notice has to be given here, that each point has an elevation value and the elevation values will help to investigate the accuracy of processing of transformation. For example, a point on a roof of building has a greater elevation value than a point on the ground. Therefore, the elevation values are one of the assessing the process of image transformation.

The STD of outputs from registering the aerial photograph on the laser scanning data consists of two STDs. The first STD is belong to matching laser scanning data with the GCPs which is for X equal 0.453, and for Y equal 0.572, and for Z is 0.3 meter. However the STD of matching each pixel with point clouds is in range of few centimetres, because the program has been developed to match each pixel with its correspondence point on the laser scanner data with accuracy of ±5cm for x, ±1cm for y, and 0cm for z. So it can be realised that the accuracy of registration processing is very much depend to accuracy of master data. The STD for output from terrestrial project is in range of few mm exactly is the similar to accuracy of 3D model.

## 5. CONCLUSION AND REMARKS

A new approach for data fusion has been created and developed. The approach is able to illuminate image distortions such as lens distortion and relief displacements while image transforming. In this approach the image is split to sub areas and each area will transferred to a 3D model pixel by pixel and the output is a point clouds or a vector image. With compare with the current image registration methods, this approach has a number of advantages. As advantages of this approach, it can be mentioned:

1- Unlike an image which its pixels geometrically connected to each other, points of outputs are geometrically independent.

2- If any part of the output has been affected by an error, that area can be individually corrected without affecting whole of output.

3- Any part ant portion of output can be easily and quickly up-to-dated without affecting all parts of the output.

4- The output can be simplified for implementing in other application such as mapping, GIS.

5- The output from this approach can be utilised in visualising.

6- The approach is able to illuminate camera and image distortion.

7- The approach is able to register a mono image on the 3D data and provide an ortho-rectify image.

8- The approach is able to combine any images that have been acquired from an object for providing more detail from the object.

Dependency of accuracy of the output to the master data is the main disadvantage of this method.

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