PARTIALLY IMAGE REGISTRATIO

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Abstract

A new method of registration of aerial photographs on Laser Scanning image has been invented. Aspirations of developing of this method were initially inspired from providing a method to improve precision as well as robustness of the product, which will be able to have multipurpose application in mapping and visualising.

This paper will be given a discussion on implementation of this method and analysed its outcomes. Due to registration of aerial photographs on Laser Scanning image, the aerial photograph was split to small parts according to geometric of objects and topography of the terrain. Then each part is transferred and registered on the Laser Scanning image. This method has capability of managing and reducing the errors and distortions, which are typically associated with aerial photographs. Due to implementing the process of registration of each part on its corresponding part on the Laser Scanning image, a search method has been developed to recognise those two parts on the aerial photographs and the Laser Scanning image.

The laser scanning image has been captured in a 3D space which is defined by geometric primitives and has been recognised as vector graphic. In contrast digital aerial photograph or digital aerial image is a raster graphic and is represented by array of pixels. The method, which has been developed for this project is able to recognise patterns on two graphic and raster graphic environments for matching and registration. Rather than implementation of pixelwise processing, which mostly is utilised for digital image matching and image registration, vector processing is utilised for matching and registration in this method. An investigation on the output from this method proves the method is reliable and precise.

Keywords: *Pixel Registration, Image Registration, Ortho-Photo, 3D Model*

1. Introduction

Image registration is implemented regarding to combine two or more images which acquired from an object or a terrain by an imagery system in different times or acquired by different imagery system in order to provide a robust output for a number of applications such as medical, agricultural, GIS, or mapping purposes. The process of image registration could be included object detecting, feature matching, transforming model estimation, and image resample and transformation (Zitova and Flusser 2003). Each step is involving a complex processing and for achieving their aspects it is required to have pre-knowledge about the image and imagery conditions. For example, for object detection it needs to apply area-based or feature-based methods. In feature-based method a segmentation method has to be implemented in order to detect a feature. The feature can be a line or a point or an arc. Image segmentation is also a complex process, which involves different methods, but basically image segmentation can be implemented by either pixel-base or object-base classifications. Following definition has been given by (Pekkarinen

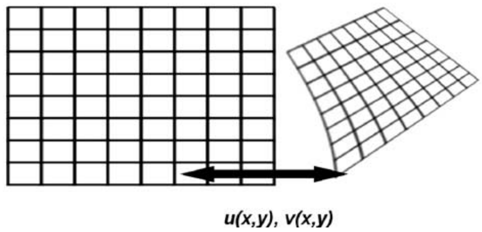
A. 2004) which it is a very short and comprehensive definition on image segmentation "image segmentation is the division of an image into spatially continues, disjointed and homogonous regions".

Digital Image Matching can be implemented in different ways, which are categorised into two distinctive methods of area-based and object-based matching. However, each of these methods has advantages and disadvantages and has been implemented for a specific application. For example, L. Di Stefano et al (2004) presented a method of fast stereo matching based on area-based matching but according to given assessment of the method, the developed method could not implement matching precisely because the system cannot cope with poor contrast between background and objects. Feature-based matching has had aspect on highlighting objects such as line or points in images. For example, Nasrabadi (1992) utilised Laplacian of Gaussian mask for highlighting curve segments, or Förstner and Gülch (1987) utilised Förstner operator for detecting points. Obviously, these methods are mostly affected by background noises, which are required to be treated by one of low pass filters. Homainejad (1997) has developed templates and an algorithm in order to provide an automatic method for object detection, matching, transforming, and tracking in real time. The templates were distributed on a test field and an algorithm was developed to recognise and detect the templates from acquired images from the test field for image matching, transforming, and object tracking.

For registration of an aerial photograph on a Laser Scanning images the following steps have to be taken:

1. Radiometric and Geometric correction have to be fulfilled on all images.
2. Providing an ortho-rectify image from stereo aerial photographs.
3. Extracting 3D data of the terrain from Laser Scanning images.
4. Building a DEM from Laser Scanning data.
5. Registering each ortho-rectify image on the corresponding part of DEM.

For transforming an aerial photographs or image on a 3D model, it is very important to know that an aerial photograph is a raster graphic and presented in a 2D array of pixels unlike a 3D model which is a vector graphic, therefore it is required to develop an algorithm which able to transfer a 2D photo on a 3D model precisely and doesn't distort the



transformed image. Figure 1 visualised a typical transforming of an image from a 2D space to a 2D space.

Figure 1. Demonstration of a typical transform of a raster image to a raster image.

In transforming of an image from a space to another space two aspects are usually under consideration. First aspect is to map an image from one space to another space. In this step, one of the methods of transformation of similarity (Eq. 1), affine (Eq. 2), or perspective transformation (Eq. 3) has to be implemented.

$$U = \mathbf{s}\,(x \cos(\square) - y \sin(\square)) + t_x$$

$$v = \mathbf{s}\,(x \sin(\square) + y \cos(\square)) + t_y$$

(Eq. 1)

$$U = a_0 + a_1 x + a_2 y$$

$V = b_0 + b_1 x + b_2 y$

(Eq.2)

$$U = \frac{a_0 + a_1 x + a_2 y}{1 + c_1 x + c_2 y}$$

$$V = \frac{b_0 + b_1 x + b_2 y}{1 + c_1 x + c_2 y}$$

(Eq.3)

It needs to reminder that for implementation of above equation is required to have at least two, three, or four control points respectively. The second aspect is to re-sampling the output image into the input image. Re-sampling is the digital process of changing the sample rate or dimensions of digital imagery by analysing and sampling the original data. Figure 2 presents the sole of process of image re-sampling.

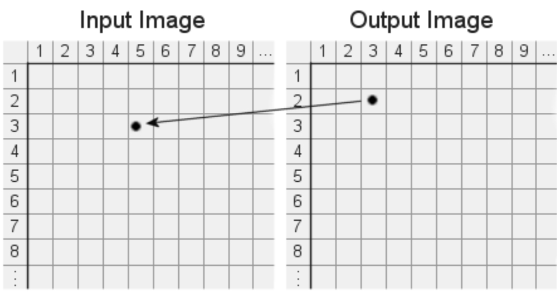


Figure 2. Demonstrating the typical re-sampling process.

Re-sampling process can be implemented "according to the required precision" by one of the Nearest Neighbourhood, or Bilinear Interpolation, or Cubic Convolution, or Cubic Spline Interpolation, or Radially Symmetric Kernels methods.

A very brief description about image registration's steps was given above. It has to be considered that after applying and implementation of all image processing for image registration the output always is not as expected. For example ortho-rectify image is an output of an image registration process, but in some certain situation, the output is distorted by geometry shape of object and terrain. Figure 3 shows an ortho-image from a high raised building. As it can be seen the high raised building overlaps other building and objects in its neighbourhood. This issue is obtained from elevation of the building and depth of view that cannot be easily treated and cause to reduce the precision of the output.

Figure 3. The highlighted areas show two multi stories building on an ortho-aerila image. As it can be seen, the taller building covers the neighbourhood areas. This issue is originated from degraded object regarding to the high and depth of view.

This paper is a report on a project for registering an aerial photograph on a Laser Scanning image. The project was fulfilled base on an initial proposal of a method based on splitting the aerial photograph to small parts according to geometry of objects and topography of terrain. Then, the Laser Scanning image is captured and compiled in a 3D model. Next each part of the aerial photograph is transferred and mapped on its corresponding part on the Laser Scanning image pixel by pixel. This method has been proposed regarding to a number of facts. The fact such as knowledge on image distortion which affects to reduce the precision of output as shown in Figure 3, were the main motivation of developing this method in order to reduce those elements which affects to the precision of the final output.

This method is able to reduce image distortion while the transforming is implemented and provide a precise output which can be used in mapping, ortho-image, visualisation, GIS, and any section which is required a precise map.

2. Study Area

This project has been implemented with the cooperation of EuroSDR on purpose to achieve a method in registration of an aerial photograph on Laser scanning image which improve the precision of output and investigate how the image resolution and laser scanning data density affect on registration accuracy, and find a method of object orientation without using field surveying. The aerial photographs and Laser Scanning images were provided by Finish Geodetic Institute and include two sets of aerial photographs and two sets of Laser Scanning images from Espoonlahti located in south of Finland.
Photogrammetric data includes DMC panchromatic image block of 4 images along DMC Multispectral images. Also the most required and applicable data were provided such as photographs orientation parameters and GCPs.

GCPs have been measured using real time kinematic (RTK) GPS and some of GCPs represent 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)

3. Methodology

The implementation of the purposed method comprises three main steps. Figure 4 shows the typical progress of these steps into a diagram. Aerial photograph is split to small parts according to geometry of objects and topography of terrain (Figure 5). As the aerial photograph was acquired from an urban area, object detection software will be applied on the image for detecting and recognising the corner of building. Two different approaches are considered in this section. The first approach is to place developed Homainejad's template (2008) on the detected building's corners manually, and the second approach is that the algorithm automatically place the templates on the detected corners. Utilising the templates makes the system is able to process the image registration automatically. All data regarding to the captured corners of the buildings will be saved in a database.

Point clouds are captured in a CAD environment along GPS coordinates of

GCP (Figure 6). A pre-analysing will be fulfilled due to investigating that all GCPs are captured in the correct location and there is no difference between the capture GCP on the 3D model and those shows in the aerial photographs. The corners of the building in 3D model will be detected and derived. All data regarding to the corners of the building in the 3D model will be saved in the second database.

Then a matching progress will be fulfilled regarding to transfer the detected object in the aerial photographs and its corresponding in the 3D model. The matching will be fulfilled base on few parameters such as coordinates, correlation of points with its neighbour points. A very important note has to be given that the correlation method which is used in this section is different with the typical correlation method which is used in image processing because in the 3D model points are defined by geometric primitives and have been recognised as vector graphic and in digital image is recognised as raster graphic. For digital matching of two overlapped digital photos, usually a number of image processing has to be implemented. Most of the image processing books (for example Bernd Jähne 2005) is describing the methods of digital image matching. In general in digital image matching, the following steps have been utilised:

- A convolution theorem can be used to evaluate matching.
- The process of segmentation has to be fulfilled on images.
- The process of correlation between a pattern in first image and the second image has to be fulfilled in order to define two corresponding pattern on two images.
- Transforming the firs image to the space of the second image or vice versa.

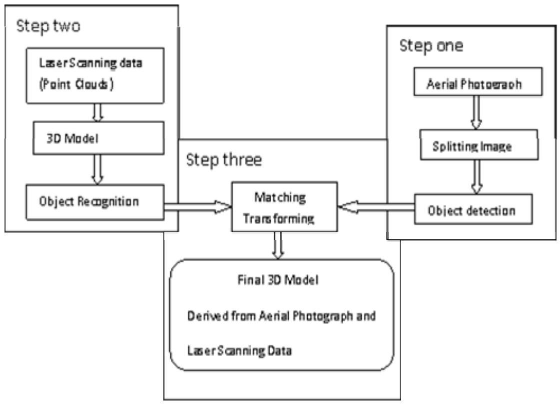


Figure 4. The process of registering aerial photographs on Laser Scanning image.

Figure 5. The way of splitting image based on geometry of objects.

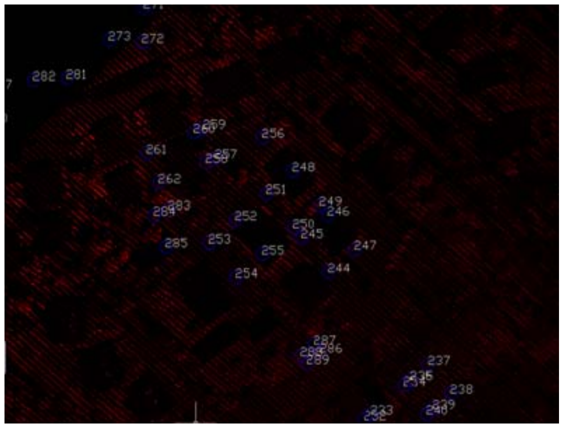


Figure 6. The captured point clouds along GCPs on a 3D model.

In contrast of the above matching explanation, in this method as soon as the corresponding area were detected and recognised on to both aerial photographs and 3D model, the process of transformation has been fulfilled for completing image registration. The object detection and matching were carried out base on vector modelling. Then each pixel of the area on the aerial photograph was individually transferred and registered on the corresponding point of the 3D model. There are a number of advantages for registering each pixel on the 3D model. For example, there is no requirement on pre-knowledge about image parameters. With applying this method of registration, a number of image distortions, which always remain with images such as those explained in Chapter 1, will be omitted and a robust and precise output will be obtained.

4. Implementation of the method and assessment of result

The sum of 2116478 points clouds, which were acquired with Leica ALS50-II, were captured and presented in a 3D model along the CGPs. An investigated was implemented to recognise and detect the corner of buildings and derived data were saved in a place for matching and registration. A multispectral DMC image was selected for registration. The image was split to small parts according to geometry of objects. As the image was acquired from an urban area, the buildings were selected for splitting the image. An investigation is fulfilled on the image for detecting the corners of building and then the developed Homainejad's template was placed on the corner of the buildings. Data related to the corners were saved in a place. Matching algorithm was applied to match between aerial image and 3D model.

Unlike the image-matching algorithm, the algorithm for matching between the 3D model and aerial image has to define the best match between a raster object and a vector data. A typical image-matching algorithm has to fulfil:

1. Pixelwise comparison
   $\sum_{x}^{x<width} \sum_{y}^{y<height} |left(x,y) - right(x,y)|$
2. Define the source of variation on the image.
3. Correlation approach.
4. Object detection.
5. Matching

The core of an image-matching algorithm is pixel value comparison and processing. In contrast, the core of the matching algorithm between a 3D model and a digital image which was developed for this project is gradient comparison and follows the following equation

$$\cos\theta = \frac{v_1 . v_2}{\|v_1\| \, \|v_2\|} \qquad \text{(Eq 4)}$$

This method has been applied for comparing the both detected objects from the aerial photographs and the 3D model. The extracted data from object detection of the aerial photographs and the 3D model were initially introduced to the matching algorithm in order to accelerating and leading the matching progress. Then each individual pixel of detected object from the aerial photograph has been transferred to the 3D space. In this step the derived object would be mapped on its corresponding object's point on the 3D model. This method has a number of advantages. For instance, it is not required to recognise the parameters of distortion, and a single image can be transferred to the 3D model whether parameters of the image orientation is available. The output from this method absolutely is more accurate than outputs, which are obtained from other methods. The output from this method consists of dots or is part of a vector graphic. A vector graphic always is more accurate than a raster graphic. The dots can be individually processed without affecting to the neighbours dots. The resolution extremely is high because unlike the pixels, a dot has no dimensions. The output has had multipurpose application, for example it can be used for a 3D visualisation, or ortho-image, GIS, or map product. For some mapping purpose such as cadastral mapping, the accuracy of output from this method still is less than required accuracy for cadastral because some limitations on digital image and laser scanning image is still preventing to recognise the parcel lands' boundaries. However, there are some potential for improving the accuracy of output of this method.

Figure 7.a shows a building on the aerial photograph before transforming, and Figure 7.b shows that building in the 3D model after transforming. The image distortion regarding the elevation of building and depth of the view can be easily seen in Figure 7.a. This distortion always remain in an image registration as it was explained in Chapter 1 (refer to Figure3), and there is a requirement for further image processing in order to remove this distortion. As one of the advantages of utilising of this method, any similar image distortion can be removed along the image transforming (refer to Figure 7.b). A further investigation on the transformed image has been carried out regarding to examine that the image's details were mapped in the correct locations as it was expected. The main aspect in this investigation was to find some obvious points on the image such as top of chimney or sunroofs or top points of roof have got right elevation as it was expected. If the transforming was incorrectly carried out or pixels were wrongly mapped on the 3D model, each point has had invalid high value. The investigation proved that the transforming has been precisely implemented and all points mapped in the correct location. The final accuracy of the output from this method is in the range of the accuracy of Laser Scanning image which the accuracy of ALS50 is: high accuracy is in the range of 13-30 cm and planimetric accuracy in the range of 11-46 cm depending on the flying high and location of point according to nadir point.

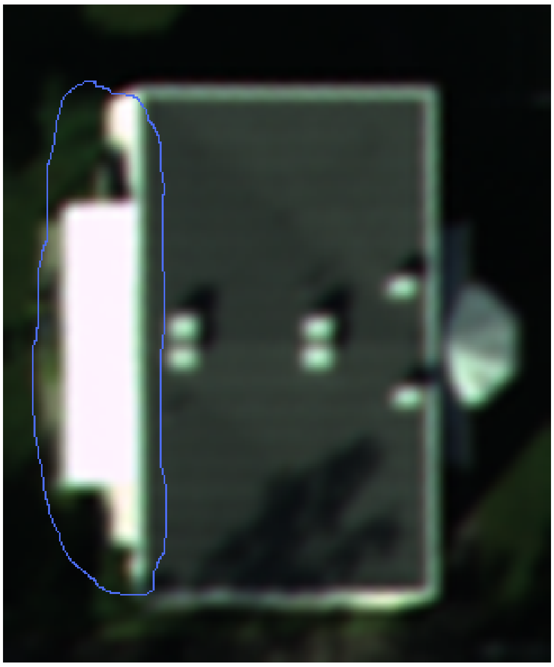


Figure 7a

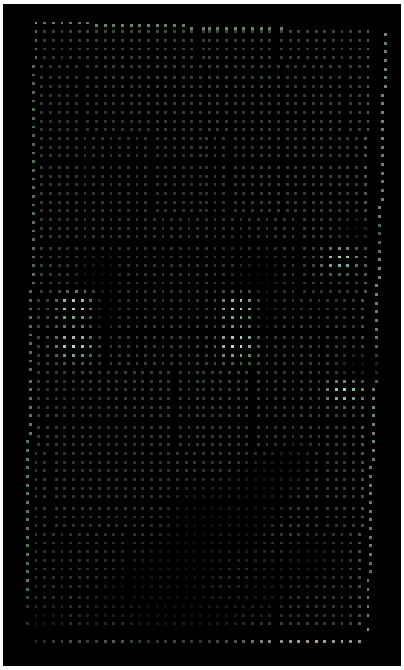


Figure 7b

Figure 7a is demonstrating a building before transforming and registering, as it can be seen the left sidewall clearly visible. This is one of the distortions relating to photo. Figure 7b shows the transferred building to the 3D space. As it can be seen the distortion was removed by utilising this method of image registration.

5. Summery

A new method for registration of aerial photograph on Laser Scanning image has been developed and invented. The method has focused on split the aerial photographs to small parts according to geometry of objects and topography of terrain, then register each individual part pixel by pixel on the corresponding points on the Laser Scanning image. The output is a vector graphic and its precision is much higher than output of image on image registration. This method has so many advantages. For example, this method is able to omit image distortion concurrent with image transformation without pre-knowledge on camera and media parameters. The precision of output is in the range of Laser Scanning image's precision. The output of this method has versatile application such as producing 3D model, visualisation, mapping, GIS, medical purpose, and ortho-image.

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