

A novel approach for constructing 3D visualised model according to registration of mono aerial photographs on laser scanning data

Dr. Amir Saeed Homainejad
Independent Research Group on Geospatial Information
Tehran, I.R. IRAN
s_homain@yahoo.com

ABSTRACT

A discussion on a new and novel approach for registering an image on a 3D model will be given. The approach was developed based on registering a mono aerial photograph on laser scanning data and did not require camera and photograph calibration parameters for processing. In contrast conventional approaches which their outputs are a raster image and are presented on a 2D plan, the output from this method is a 3D vector model which has broad perspective in visualisation, mapping, GIS, planning, etc. The main advantage of this approach is to omit camera distortions, and the output from this approach is precise and very reliable. The accuracy of the output depends on accuracy of master data. This approach is very versatile, and able to register any image on DEM, DSM, and topographic 3D model.

Keywords: Image registration, Laser scanner data, 3D model, point clouds

1. Introduction

One of the aspects of image registration is ortho-image production. The main advantage of photograph and images over other imagery systems is screening detailed information from objects; however, the geometrically distortion is the main disadvantage of images. Geometry stability is the first priority in map production and for utilising images as a map, it is required to register images on an existing map, or rectified image, or DTM. Indeed a number of studies for ortho-image production and ortho-image application have been registered on an existing map, or rectified image, or DTM such as Kerschner (2001), Marten et al (1994), and Jyothi et al (2008). The process of image registration consists of four steps of object detecting, matching, estimation of transform model, and image resampling and transformation. The core of image registration for map production has focused on defining a relationship between the image space which follows perspective projection rule and object space which follows orthogonal projections rule. Figure 1 demonstrates this relationship. For transferring an image on a map or rectified image, it requires to have at least four Ground Control Points (GCPs) on the terrain. The GCPs have to be chosen carefully; hence, they make a good balance with the whole of the terrain. Usually after registration, the output is not free of distortion and always consists of distortion in some extent. For example Figure 2, which is derived from tutorial material which was given by Baltsavias et al at ISPRS Technical Commission IV Symposium (2006) is presenting an output of ortho-image. Distortions very clearly can be recognised from original image (Figure 2a), and it can be realised that most of distortions have been removed and corrected in the ortho-image. If one has had another look on the ortho-photo for a second time carefully, some distortions can be recognised, as highlighted in Figure 3. The relief displacement is the main cause of producing of this kind of distortions and it is almost impossible to remove this kind of distortion with the existing approaches.

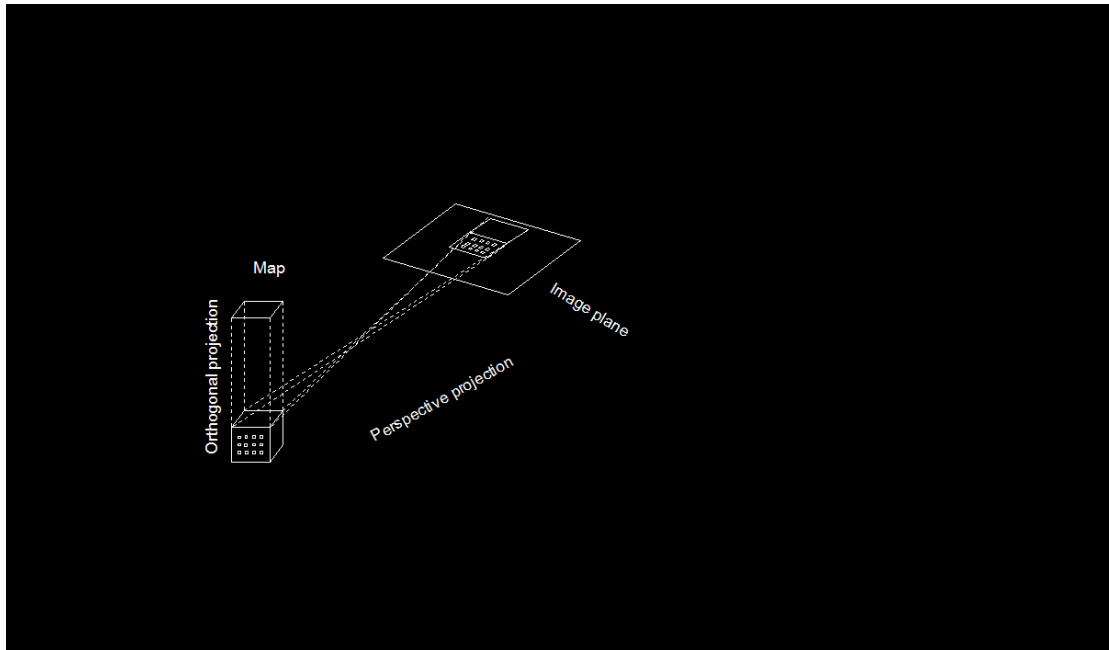


Figure 1: Demonstration of orthogonal projection versus perspective projection. As it can be recognised the objects are laying from centre of image towards the sides of image in perspective projection.



Figure 2a



Figure 2b

Figure 2: Demonstration of an image and its ortho-image. As it can be seen most of image distortions on Figure 2a have been rectified in Figure 2b. This Figure is extracted from tutorial material presented by Baltsavias et al (2006).

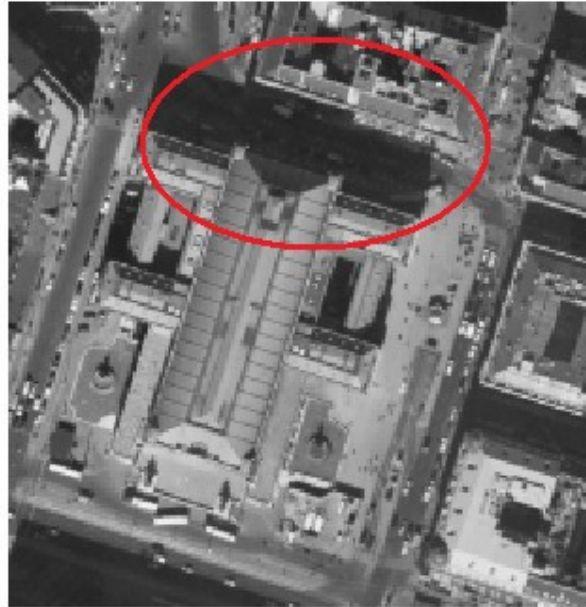


Figure 3: Image distortion regarding to relief displacement on ortho-image. The facial of the highlighted building can be seen. It is required that an ortho-rectify-image has no any kind of distortions, if it will be used as a map.

This paper is a report of a study on registering of an image on a 3D model. The core of this study has focused on removing any distortions from output with the minimum knowledge regarding to the camera parameters, and output has geometry stability which can use as a map. It was proposed to divide the image to small areas according to terrain's topography and object geometry. Then, each sub-area would be transferred to its correspondence area on a 3D model pixel by pixel. The output will be free from any distortions and pixels would be converted to point clouds. This paper will explain the registration of DMC colour and panchromatic images on Leica and Optech laser scanners data.

This paper has been organised as following. The methodology has been given in next chapter, chapter three will discuss about implantation and result, chapter four will analyse the output, and finally remarks and summery will be given on chapter five.

2. Methodology

The process of the developed image registration that is mentioning in this report is different from existing conventional approaches in image registration. The objectives for developing of this approach are:

- 1- To remove any image distortions,
- 2- To produce a robust output,
- 3- To reduce on using GCPs and camera calibration parameters.

It is known that all images are a restricted plane that their elements are joints to each other, and any image processing has to be implemented in this plane. This character of image is the most setbacks in image registration. The main aspect of image registration is to remove image distortions, some distortions have been generated with the deep and high of objects and they cannot be treated easily and always they are remain on the images. In conventional image registration, the rotation angles of image around three axis of X, Y, Z (R_x , R_y , R_z) are computed and then will be applied on image registration process for removing any distortion which were generated according to these rotations. One of the most disadvantages of this process is that the output is not an orthogonal projected image. It means that after rotating image around X, Y, Z axis the rotated image has to be orthogonally project on a plane, and the output will be a pure ortho-rectify-image, in addition, the output is free from any rotational distortion. This is the sole of image registration; however, existing techniques are not basically able to produce a pure ortho-image. The missing part from image registration is orthogonal projection of rotated image on a plane, and with existing techniques orthogonal projection of an image is impossible. Consequently, the output of an image registration has included distortions in some extent (Figure 3).

According to above knowledge, a new approach on image registration has been proposed and developed for removing any distortion from image and produce a robust output. The image has been divided to small areas according to geometry of object and topography of terrain, along a 3D model from the terrain has been captured on the computer. Then each sub-area is transferred on the correspondence area on the 3D model pixel by pixel. By implementing of this method indeed each sub-area will be rotated according to (R_x, R_y, R_z) and orthogonally projected on a plane. The advantage of utilising this method is to skip of utilising of camera calibration, and process can be implemented on a mono image.

3. Implementation and output

Two set of data have been undertaken in this project. The first set data was provided by EuroSDR which consist of panchromatic and colour image have been acquired by Intergraph DMC from Espoonlahti at south of Finland along two laser scanners data from that area which were acquired by Leica ALS50-II and Optech ALTM 3100.

At first Leica and Optech data have been captured individually and together in the computer, indeed three 3D models from Leica data, Optech data, and Leica with optech have been developed in the computer. Then, the panchromatic and colour images have been divided to small area according to geometry of object and topography of terrain. In next step, sub-areas from panchromatic and colour images were transferred to their correspondence area on each 3D models. At first the panchromatic image was transferred to Leica, Optech, and Leica and Optech 3D models. Then the sub-areas from colour image were transferred to 3D models. Six individual transferred data have been obtained. A note has to been given here that the transferred image indeed is a point clouds data. Each pixel from image will be transferred to its correspondence point on the 3D model and has taken three coordinates of X, Y, Z which indicates the position of the pixel on the 3D model and pixel intensity values. Figures 4 to 9 presents the original image and outputs from transferring panchromatic and colour images on 3D models.



Figure 4: Original image from one of areas which have been chosen for image registration. The relief displacement's effect on the image can be easily recognised. The facial of buildings can be seen.



Figure 5: The output of registration of the colour image on the Leica laser scanner data. The blank area in the red circle indicates that the relief displacement has been omitted because image of building was pulled back and rectified consequently a blank area appears in the output in the place. As the output is point clouds this blank area can be fixed easily by different techniques.



Figure 6: The output of registration of the colour image on the Optech laser scanner data. Same Figure 5 the effect of relief displacement has been omitted in this output.



Figure 7: The output of registration of the colour image on the combined laser scanner data. It can be seen that the effect of relief displacement has been omitted.



Figure 8: The output from registration of the panchromatic image on combined laser scanner data. It can be recognised that relief displacement has been fixed.

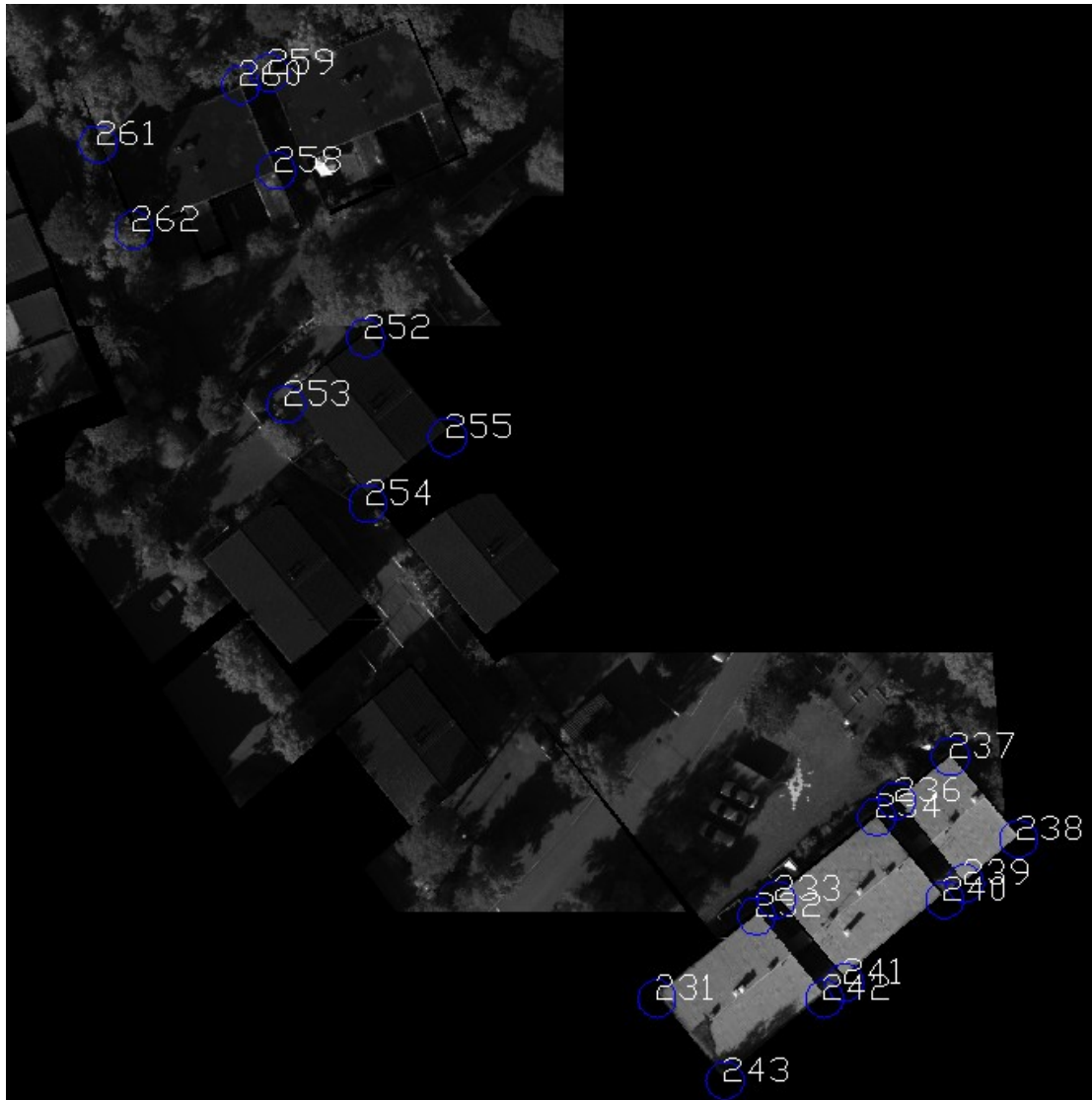


Figure 9: The output from registration on panchromatic image on Leica laser scanner data with superimposed GCPs provided by EuroSDR.

4. Analysis of outputs

Each output has been investigated versus distortion and accuracy. Transferred images demonstrated that free from distortions produced by relief displacement. With close looking at Figures 5, 6, 7, and 8 it can be realised there are some blank areas between ground area and building which were caused by relief displacement. That building in an orthogonal projection has two dimensions on X, and Y directions, but aerial image (Figures 2 and 4) shows the third dimension of the building, in addition building was laid on the side in the image (Figure 1). If an orthogonal projected image was available from the building, the image of roof of building has to be pulled back at the correct location as shown in Figures 5 to 8. The distance between the building and the ground area on the outputs is the replacement distance of building according to relief displacement. The developed approach that has been utilised for this project has transferred the image on the correct location and omits the distortion regarding to relief displacement. The gap can be easily filled by different ways. For example, the gap can be filled according to any existing images from that part or can be filled by creating new point clouds for that part.

EuroSDR has provided a number of GCPs which were obtained by GPS. The accuracy of GCPs hasn't been provided. In this study it was presumed that GCPs are free from any error and then extracted data were compared with them. If there were any differences, it was considered that extracted data had errors; however, this kind of comparison is not recommended in science. Tables 1, and 2 show the comparison of extracted data versus provided data. It can be recognised that extracted data for transferring image on Leica and Optech in X and Y and Z direction is in range of few centimetres to

maximum one meter that this rang of error is in the range of point uncertainty and is acceptable. A note has to be given that a few of GCPs are surrounded by tall trees and those trees affected to the extracted data. With a very close investigation on areas which the differences between the provided GCPs and extracted data are more than one meter it was realised those areas are surrounded with tall trees and too many scattered data are available for those area. This issue proves that the accuracy of outputs from this approach is very close to the accuracy of point clouds.

		Provided by EuroSDR			Extracted data					
		X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ
23	1 roof	369450.817	6669932.425	46.612	369450.213	6669931.424	46.742	0.604	1.001	-0.131
23	2 roof	369461.458	6669941.186	46.627	369461.250	6669940.378	46.655	0.208	0.808	-0.029
23	3 roof	369463.587	6669942.948	46.355	369463.406	6669942.262	46.404	0.180	0.686	-0.049
23	4 roof	369474.240	6669951.763	46.221	369473.969	6669950.660	46.561	0.271	1.102	-0.341
23	6 roof	369476.371	6669953.505	46.021	369476.285	6669952.855	46.108	0.086	0.650	-0.087
23	7 roof	369482.108	6669958.239	45.974	369481.750	6669957.361	46.121	0.358	0.878	-0.147
23	8 roof	369489.357	6669949.420	46.032	369488.625	6669948.927	45.956	0.732	0.493	0.076
23	9 roof	369483.633	6669944.693	46.044	369483.156	6669944.306	46.011	0.477	0.387	0.032
24	0 roof	369481.512	6669942.919	46.240	369480.656	6669942.284	46.226	0.856	0.634	0.014
24	1 roof	369470.833	6669934.162	46.286	369470.375	6669933.561	46.165	0.458	0.601	0.121
24	2 roof	369468.716	6669932.422	46.619	369468.063	6669931.482	46.598	0.654	0.941	0.021
24	3 roof	369458.071	6669923.642	46.648	369457.250	6669922.181	48.985	0.821	1.460	-2.337
25	2 roof	369419.814	6670002.791	49.997	369419.438	6670002.782	49.840	0.376	0.009	0.156
25	3 roof	369411.332	6669995.758	49.986	369410.938	6669996.260	49.868	0.395	-0.502	0.118
25	4 roof	369420.059	6669985.199	50.004	369419.531	6669985.099	49.972	0.528	0.100	0.031
25	5 roof	369428.533	6669992.232	50.027	369427.938	6669992.208	50.101	0.596	0.024	-0.074
25	7 roof	369413.376	6670021.940	46.257	369413.219	6670022.084	46.057	0.157	-0.145	0.199
25	8 roof	369410.359	6670020.668	46.229	369410.000	6670020.620	45.636	0.358	0.048	0.593
25	9 roof	369409.560	6670031.107	46.231	369409.375	6670031.725	46.084	0.185	-0.617	0.147
26	0 roof	369406.495	6670029.815	46.239	369406.094	6670030.321	45.946	0.401	-0.507	0.293
26	1 roof	369391.299	6670023.475	46.217	369390.906	6670023.610	45.993	0.393	-0.134	0.223
26	2 roof	369395.166	6670014.322	46.239	369394.906	6670013.969	49.561	0.260	0.353	-3.321

Table 1: Comparison between GCPs have been provided and extracted data from transferred image on the Leica laser scanner data. As it can be recognised the differences are in the range of few centimetres and maximum one meter within the range of point uncertainty. The areas with differences more than one meter are surrounded by tall trees. This issue can be resolved by applying a special filtering for those individual points.

		Provided by EuroSDR			Extracted data					
		X	Y	Z	X	Y	Z	Δx	Δy	Δz
23	roof	369450.817	6669932.425	46.612	369451.000	6669933.080	46.930	-0.183	-0.655	-0.318
23	roof	369461.458	6669941.186	46.627	369461.781	6669941.910	46.915	-0.323	-0.724	-0.288
23	roof	369463.587	6669942.948	46.355	369463.812	6669943.427	46.896	-0.226	-0.479	-0.541
23	roof	369474.240	6669951.763	46.221	369474.219	6669951.617	46.960	0.021	0.146	-0.739
23	roof	369476.371	6669953.505	46.021	369476.469	6669953.664	46.711	-0.098	-0.159	-0.690
23	roof	369482.108	6669958.239	45.974	369481.813	6669957.981	46.504	0.295	0.258	-0.530
23	roof	369489.357	6669949.420	46.032	369488.750	6669949.902	46.403	0.607	-0.482	-0.371
23	roof	369483.633	6669944.693	46.044	369483.250	6669945.364	46.472	0.383	-0.672	-0.428
24	roof	369481.512	6669942.919	46.240	369481.031	6669943.538	46.538	0.481	-0.620	-0.298
24	roof	369470.833	6669934.162	46.286	369470.812	6669935.072	46.658	0.021	-0.910	-0.372
24	roof	369468.716	6669932.422	46.619	369468.531	6669933.080	46.984	0.185	-0.657	-0.365
24	roof	369458.071	6669923.642	46.648	369458.000	6669924.170	48.850	0.071	-0.528	-2.202
25	roof	369419.814	6670002.791	49.997	369419.375	6670003.175	50.325	0.439	-0.384	-0.329
25	roof	369411.332	6669995.758	49.986	369411.531	6669996.655	50.601	-0.199	-0.897	-0.615
25	roof	369420.059	6669985.199	50.004	369420.062	6669986.463	50.270	-0.003	-1.264	-0.267
25	roof	369428.533	6669992.232	50.027	369428.344	6669993.148	50.110	0.189	-0.916	-0.083
25	roof	369413.376	6670021.940	46.257	369411.844	6670022.035	46.669	1.532	-0.095	-0.412
25	roof	369410.359	6670020.668	46.229	369408.906	6670020.586	46.128	1.452	0.082	0.101
25	roof	369409.560	6670031.107	46.231	369408.406	6670030.349	46.531	1.154	0.758	-0.300
26	roof	369406.495	6670029.815	46.239	369405.500	6670029.115	46.387	0.995	0.700	-0.148
26	roof	369391.299	6670023.475	46.217	369391.937	6670023.322	46.635	-0.638	0.153	-0.418
26	roof	369395.166	6670014.322	46.239	369395.500	6670014.902	45.053	-0.334	-0.580	1.186

Table 2: The table gives a comparison between provided GCPs and extracted data from transferred image on the Optech laser scanner data. As it can be seen the differences is in the range of point uncertainty range. For improving output, registration of image on the combined that is recommended.

5. Summery and Remarks

A new approach for registering an image on a 3D model has been developed and implemented. By utilising of this approach can reach to a number of advantages such as reducing any distortion and not requirement of utilising camera calibration in processing. The image has to be divided to sub-area according to geometry of objects and topography of terrain. Then each sub-area has to be transferred on its correspondence area on a 3D model pixel by pixel. After transferring, the pixels will be converted to

point clouds. The accuracy of the output from this method is dependent on the accuracy of master data. The output is a pure ortho-rectify image which can be utilised for various purposes such as mapping, 3D model visualising, and GIS.

6. References

- Baltsavias, E., Zhang, L., Holland, D., Srivasata, P.K., Gopala Krishna, B., Srinivasan, T.P., (27-30 September 2006), "Extraction of Geospatial Information from High Spatial Resolution Optical satellite Sensors", ISPRS Technical Commission IV Symposium "Geospatial Databases for Sustainable Development", Goa, India
- Kerschner, M., (2001), "Seamline detection in colour orthoimage mosaicking by use of twin snakes", ISPRS Journal of Photogrammetry and Remote Sensing, Vol 56, Pages 53-64
- Jyothi, M.V., Radhadevi, P.V., Solanki, S.S., (2008), "Topographic data bases inproduct generation of IRS_P6 Liss_4 Imagery", ISPRS Journal of Photogrammetry and Remote Sensing, Vol 63, Pages 322-332
- Marten, W., Mauelshagen, L., Pallaske, R., (1994), "Digital orthoimage-system for architecture Representation", ISPRS Journal of Photogrammetry and Remote Sensing, Vol 49, Pages 16-22