Orthomosaic from Generating 3D Models with Photogrammetry

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Abstract:- This paper, especially discuss the getting of three coordinates for points in two images by processing these images to 3D models by Photogrammetric program. Agisoft is openly utilized functions that developed algorithm used in a field called Computer Vision which needed for processing images to 3D models. Computer Vision is a sub-field of computer science that was prepared to help robotic equipments to clarify surrounding bodies. Computer Vision algorithms detect common points among photos of a given objective, possessed from various angles, and process those photos to conclude depths of the structures. There are four basic steps: Align Photos, Build Dense Cloud, Build Mesh, and Build Texture and two secondary steps: Build DEM, Build Orthomosaic. Additionally, there are a number of tasks with related sub-settings of the basic procedures of Agisoft that developed by author to refine the results of these processes. Regrettably, user guide of Agisoft has not been used correctly in the factors and the effect of each sub-setting. In order to quite understand the concepts and functions of sub-settings to refine the output results, the author reached an experiment in which he created Photogrammetric model of the building were processed using various sub-settings. It is not as simple as some program, but it have more better cog of all step of operation, and produce much more accurate results.

I. INTRODUCTION

Photogrammetry is a measurement method where the coordinates of the points in 3D of an object are computed from the measurements made in two photographic images (or more) taken starting from a different position.

Generally, the Photogrammetry can be divided into two types the aerial photogrammetry and terrestrial photogrammetry. The aerial photogrammetry is used for developing particular and public grounds and production of topography maps. On the other hand, the terrestrial photogrammetry can be used for surveying on the ground level for small scale, manufacturing and industrial applications. Terrestrial is also defined as digital close range photogrammetry (DCRP). Recently, the using of digital photogrammetry becomes considerably better comparing with traditional photogrammetry, since all images are now a digital format, furthermore, due to the low cost of digital cameras, storage media and processing systems. The digital image is used in different fields and applications.

II. THE WORKFLOW TAB IN AGISOFT

Agisoft do the arrangement of processing by Workflow tab. The processing is done by navigating during the tab and executing all tasks below;

➢ *Adding Images*
- In this stage, images are loading to the program.
➢ *Aligning Images*
- In this stage, the searching of finding the same pixel between images and guess the position of camera and object model from matching.
➢ *Dense Cloud Building*
- After completing the second phase, just a portion of the points is handled to a dense point in 3D space.
➢ *Mesh Building*
- In this stage, links every group of three neighboring points into a trigonal face, that join easily to product a mesh above the exterior of the body.
➢ *Texture Building*
- This stage interested in built-up the texture depending on main first images and cover the mesh to reach for the real object
➢ *DEM Building*
- This is the penultimate step in which heights are positioned for the model based on images.
➢ *Orthomosaic Building*
- This is the last step, in which an image of the model is taken and this image contains the coordinates for each location in the image.
So as to get better outcome, there is a different way into the program, except the basic procedures, this paper take the main and sub-setting workflow.

III. CAPTURING AND ADD IMAGES

The first step is obtaining the data,take images with your camera and then place them on your computer to use in the software.

All imaging work was done with one camera Canon EOS 500D Furthermore the image dimensions was 4752x3168 pixels. Moreover the acquired images are in the form of pairs that g100% overlap and hence more efficient coverage of the object. With manual setting, the focal length is 50 mm over that, the (image stabiliser) mechanisms was averted in work of imaging to preserve stability, where all The listed pixel positions must illustrate a repeatable measure for point and the shutter speed was f/5.

So the ISO increased if more sensitivity is necessary in low lighting case, for the condition of this study the used ISO was 100 with no flash.

Fig 1:- Left image and Right image

IV. ALIGNING IMAGES

It is the step to give the images for the software to compare the images and find the matching points between the images by an auto matching process illustrate in figure (2), which the software is based on functions that let the user to get coordinates (x , y) in pixel of matching points in each image , illustrate in table (1) . This is the fascinating component of the Photogrammetry process, without that nothing else would run.

After uploading images into the software, the first step of a constructed model is Aligning images. The software allows to user to choose the accuracy of matching from low to highest passing through classes between them. Highest accuracy uses full resolution image, and Lowest accuracy uses 10% resolution. The next sub-setting is Pair Pre Selection; this sub-setting allows to Agisoft do a quick pre-scan before it starts full common points detection in the image. This quick pre-scan can find two images that share the same views. Depend on this pre-scan, Agisoft can skip the entire image point detections to align each single photo. Instead of, it only scanning two pre-selected images every time to find camera position. As a result, use Pair Pre Selection will reduce processing time.

The second step of Align images sub-setting is Key Point Limit. This setting allocates how many pixels Agisoft uses from every image to detect features in the photo. The default setting of Key Point Limit is 40,000 (for reference, a typical 36 Megapixel image has approximately 240,000 pixels, and a 21 Megapixel image has approximately 180,000 pixels). Selecting a high number for Key Point Limit will rise the working time until the value reaches 240,000, providing full processing of images having 36 Megapixels (240,000 pixels), (stated in One Agisoft forum discussion). However, the forum also illustrated that if the setting selected for Key Point Limit is more than 40,000, there will be no refinement in the quality of Dense Clouds in next processing. so ,if accuracy is the main regard, projection error can be reduced to 0.3 pixels by rising Key Point Limit to 120,000 (although a rate projection error with Key Point Limit set to 40,000 is 0.7 pixels--already less than 1 pixel) (Marcel, 2015). The author chose the Align images process with Key Point Limit: 40,000 (default) and Key Points Limit: 90,000 (Fig. 3 and 4). There is no noticeable difference in the development of the formed sparse points. The outcome must be a scattered points for the body.
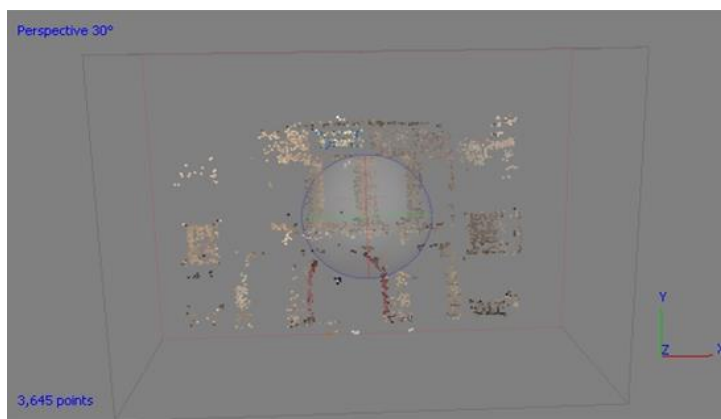
Fig 2:- Auto Matching between images

Fig 3:- Align images process with Key Point Limit: 40,000 (default) setting. Total number of sparse points were 3,645
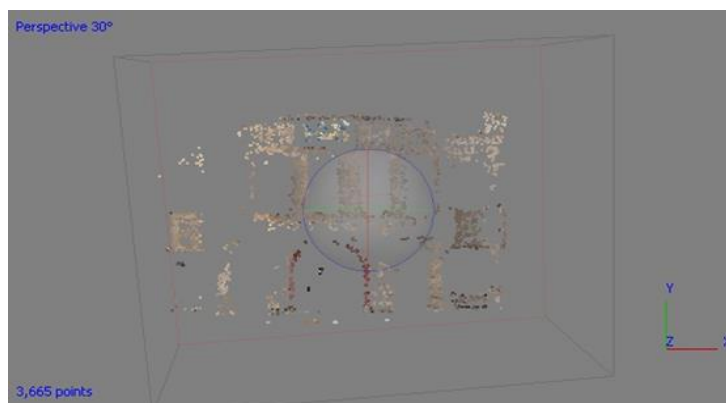

Fig 4:- Align images process with Key Point Limit: 90,000 (default) setting. Total number of sparse points were 3,665

As we note there is no noticeable difference in the number of spare points, where in the first case 3645 spare points and in the second case there is 3665 spare points, With a significant and tangible variance in Key Point Limit.

Left image			Right image		
ID	**X**	**Y**	**ID**	**X**	**Y**
1	10.985	0.579	1	9.324	0.828
2	7.041	0.383	2	4.707	0.603
3	1.874	0.23	3	-1.117	0.429
4	1.074	0.192	4	-1.898	0.395
5	8.902	0.196	5	7.195	0.439
6	8.983	0.197	6	7.283	0.439
7	4.229	0.158	7	1.316	0.365
8	4.379	0.157	8	1.476	0.363
.					
.					
.					
.					
.					
.					
3636	1.901	6.372	3636	-0.983	6.362
3637	2.826	6.375	3637	-0.043	6.394
3638	9.489	6.369	3638	8.39	6.69
3639	2.215	6.168	3639	-0.67	6.171
3640	4.695	6.032	3640	1.958	6.116
3641	5.039	5.994	3641	2.352	6.09
3642	6.448	5.915	3642	4.064	6.068
3643	4.701	5.875	3643	1.956	5.962
3644	5.273	5.745	3644	2.621	5.853

Table 1: Matching point between image from aligning phase

The final sub-setting of the Align images step is Tie Point Limit, which allows how many detected common points are truly applied to calculate the depth of the scene. For instance, when 40,000 Key Point Limit and 2,000 Tie Point Limit are applied, 40,000 points of each photo are used to detect common points to match photos, and then the 2,000 highest quality common points for each photo are used to estimate camera locations and to produce point clouds. Reducing the Tie points setting that lead to reduce the processing time of image alignment. In the Align images stage the author applied a setting of Tie Point Limits: 2,000 (default) and Tie Point Limit 4,000; increasing the number of tie point limits to twice more than doubled the number of formed sparse points, but at a cost of a significantly longer processing time (Fig. 5 and 6).

Depending on the results, the Tie Point Limit value immediately impacts the overall number of sparse points. The author decided not to do experiments on the Quality sub-setting at this phase of processing because successful image alignment generally based on photo-shooting, not Quality sub-settings
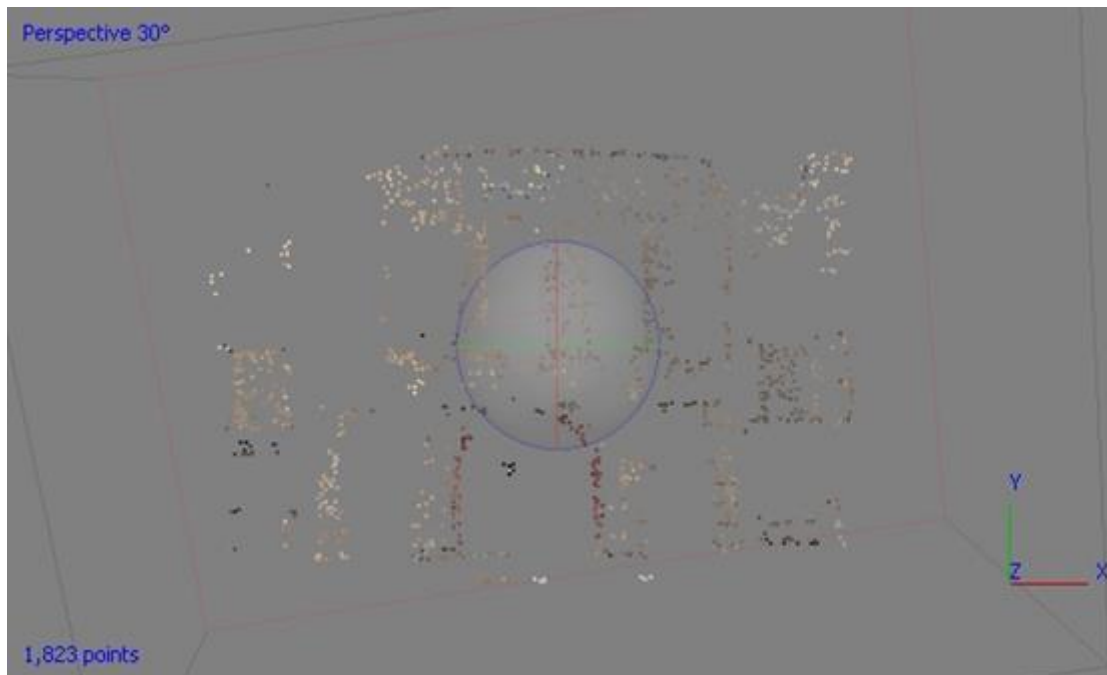

Fig 5:- Align Photos process with Tie Point Limits: 2000 (default) setting. Total number of created sparse points were 18,489.
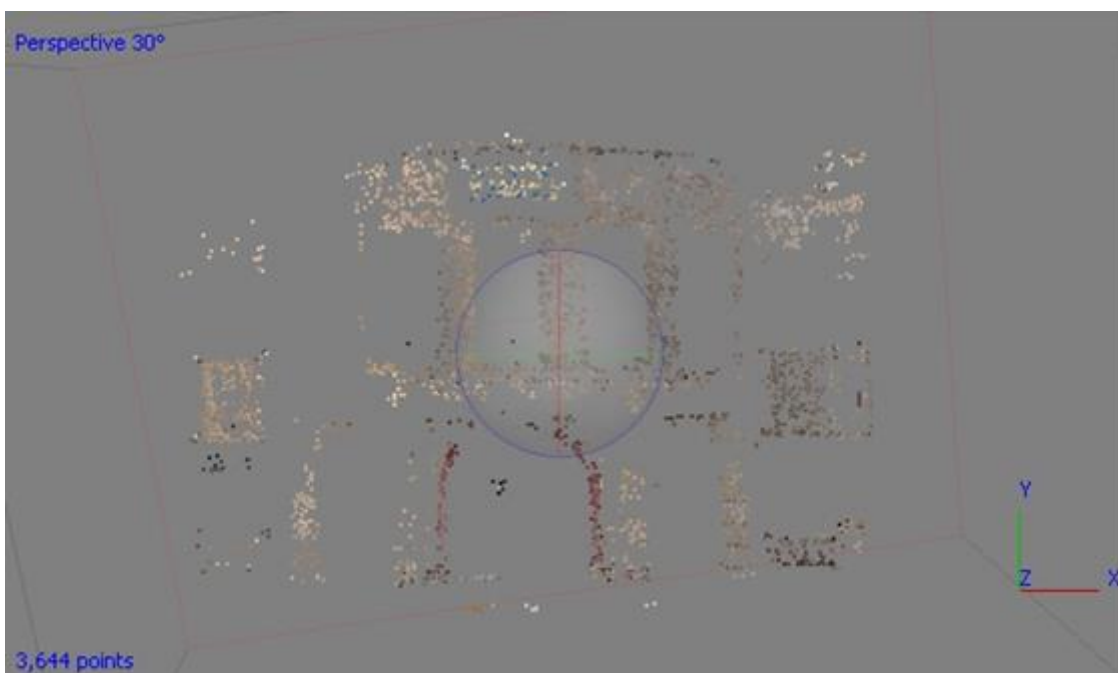

Fig 6:- Align Photos process with Tie Point Limits: 4000 (default) setting. Total number of created sparse points were 18,489.

V. EDITING THE SCATTERED CLOUDS

The moment that leads to unconvinced with the aligning of all images, it should be remove of any obviously invalid points. Use the indented-circle-shaped lasso tool to choose points and selected them in another color and remove these points. When you reach to satisfy, then structure the dense from excerpt all the useful data from every image.
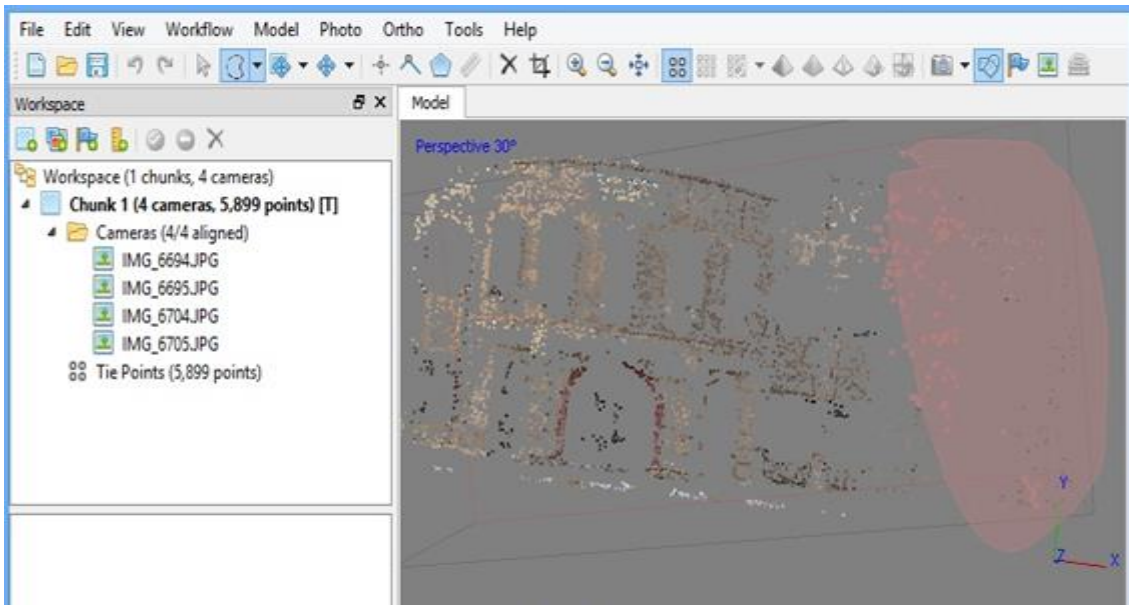

Fig 7:- Scattered Clouds

VI. DENSE CLOUD BUILDING

In this stage, it uses the images that aligned to create a new cloud points, which intense appropriate to build a model that appear from a distance. This stage is divided into two parts: the first is to get the points resulting from the process of forward intersection to points of auto matching in the alignment phase and their number (3644 points) as shown in table (1), and the second part is the process of dense these points, it will become their number (7,164,195 points points) As shown in the table (2) .It can adjust the Quality rate of dense as wished for, This quality process has five settings: *Ultra High, High, Medium, Low*, and *Lowest*. Ultra High quality uses a full size image resolution, High uses 50% of the original scale, Medium uses 25%, Low uses 12.5%, and Lowest uses 6.75%. These percentages immediately impact the total number of points in the dense cloud (Fig. 8).

The result of this stage when quality is Ultra high was (7,164,195 points), High (2,156,384 points), Medium (573,862 points), Low (142,389 points), Lowest (34,884 points).
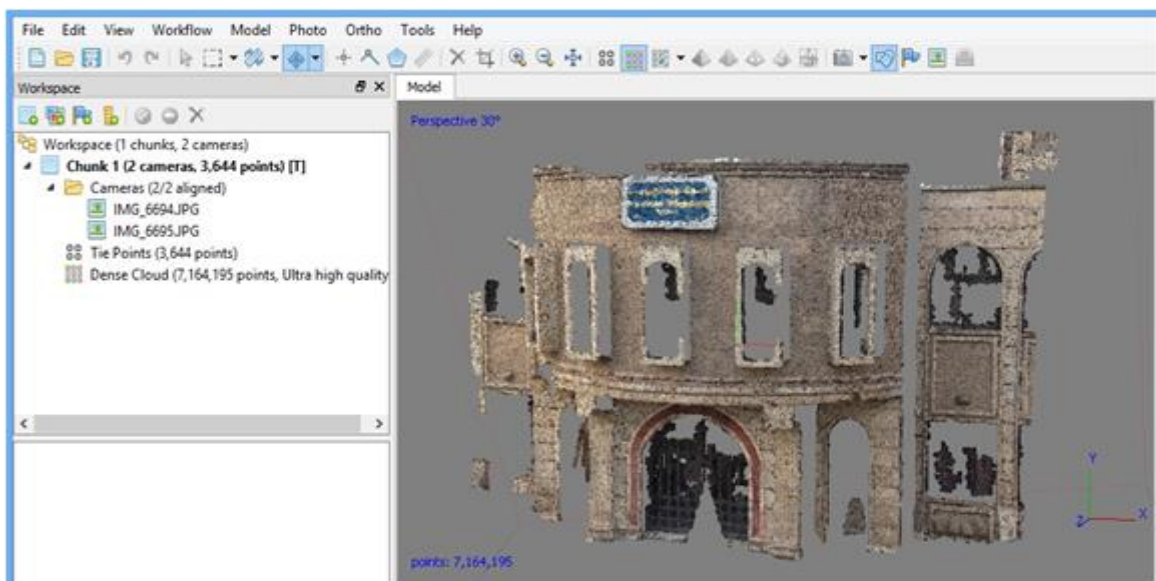

Fig 8:- Dense Cloud

Points Dense Cloud			
ID	x	y	z
1	-1.92114	0.146128	-3.33072
2	-1.91918	0.15541	-3.33179
3	-1.91525	0.164334	-3.32858
4	-1.92061	0.166833	-3.33162
5	-1.91757	0.126316	-3.3243
6	-1.91793	0.131492	-3.32662
7	-1.91525	0.152375	-3.3293
8	-1.92061	0.161121	-3.33197
9	-1.91846	0.162549	-3.33126
.			
.			
.			
2138786	-1.91543	0.132028	-3.32412
2138787	-1.91936	0.142916	-3.32715
2138788	-1.9165	0.142916	-3.32733
2138789	-1.91989	0.166119	-3.33144
2138790	-1.91614	0.153089	-3.33019
2138791	-1.91846	0.12703	-3.32519
2138792	-1.91846	0.164691	-3.33179
2138793	-1.91525	0.162192	-3.32876
2138794	-1.92025	0.143094	-3.32894

Table 2:- Point Dense Cloud

The second sub-setting is Depth Filtering. This filter has four list options: *Disabled, Mild, Moderate*, and *Aggressive*. The Aggressive option means that if the object is monotone, Agisoft will make it as void space and will not generate points within that space (Fig. 9).

Choosing the Mild option induce the program to distinguish the monotone areas as objects, and to generate points within those spaces (Fig. 10). For instance, the Aggressive depth filter does not distinguish the surface of a whiteboard as an object, and it generates a hole in its photogrammetric model; on the other side, the Mild setting may distinguish blue sky as a blue object, and thus generates point clouds in what would otherwise be void space. So , Mild works well on a monotone surface, and Aggressive works well with photos that contain actual void spaces. Moderate filtering works between the previous two filtering options (Fig. 11). The disabled mode does not distinguish depth; that's mean, if an object has a monotone colored surface, Agisoft does not regard it as a surface and generates void spaces (Fig. 12). In summary, all depth filtering selections have advantages and disadvantages, thus the Depth Filtering setting must be selected depending on photography conditions.

Fig 9:- Build Dense Cloud process with Depth filtering: Aggressive setting.

Fig 10:- Build Dense Cloud process with Depth filtering: Mild setting.

Fig 11:- Build Dense Cloud process with Depth filtering: Moderate setting.

Fig 12:- Build Dense Cloud process with Depth filtering: Disabled setting.

VII. BUILDING MESH

The dense cloud appears big solid object, but seems actual cloud points as the name propose when zoom in it. So , the next step is Build Mesh (mesh is the geometry of the generated model depending on the point cloud). The mesh will connect the point cloud into faces to make a continuous surface.

In this process the sub-settings are divided into general options contains (*Surface Type*, *Source Data*, *Face Count*), and advance options contain (Interpolation, and Point Classes) (Fig. 12). Surface Type has options *Height Field (2.5D)* and *Arbitrary (3D)*; when the object is a flat structure, Height Field (2.5D) is appropriate; but, if an object has 3D structure, Arbitrary (3D) must be chosen (Fig. 13 and 14). Either Sparse Cloud or Dense Cloud may be chosen from Source data. Generally, Dense Cloud is the best since it generates more close details.
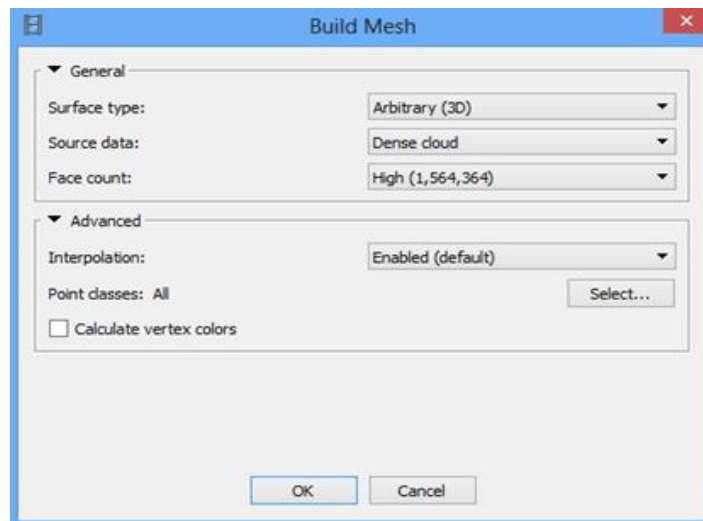

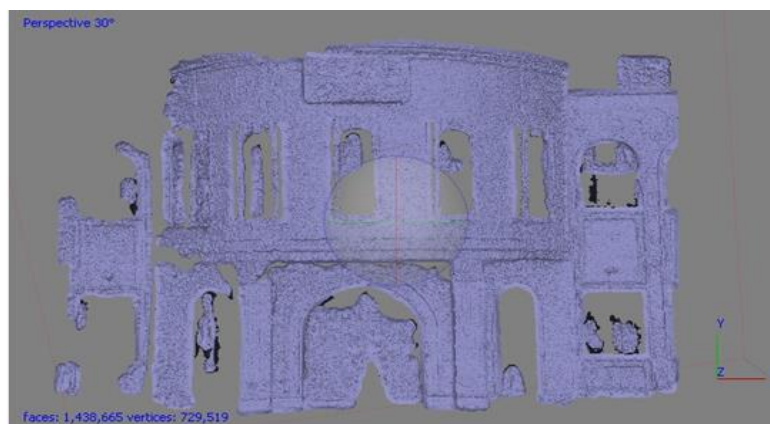Fig 13:- Mesh sub-settings

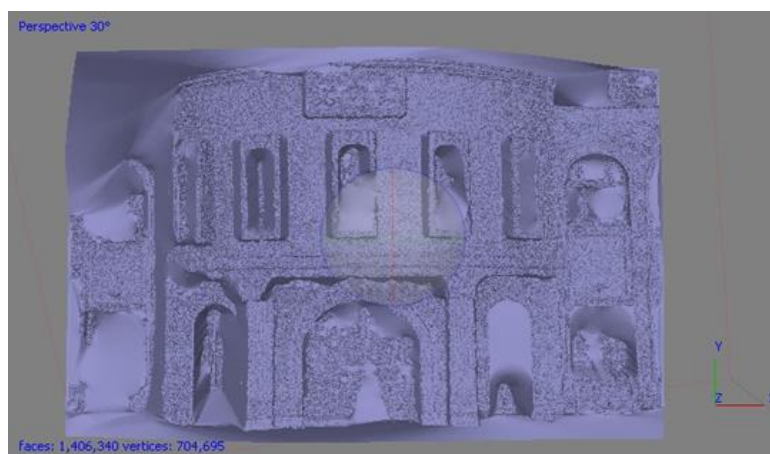Fig 14:- Build Mesh process with Surface Type: Arbitrary setting.

Fig 15:- Build Mesh process with Surface Type: Height Field setting.

The Face Count (Face Count means the total number of the generated surface of the mesh) sub-setting has *High, Medium*, and *Low* options; High generates faces, or surface of meshes, that are made of 1/5 of points in the Dense cloud points, Medium generates 1/15 of the point cloud (1/3 of the High setting), and Low generates 1/45 of the point cloud (1/9 of the High setting) (Fig. 15, 16 and 3-17).
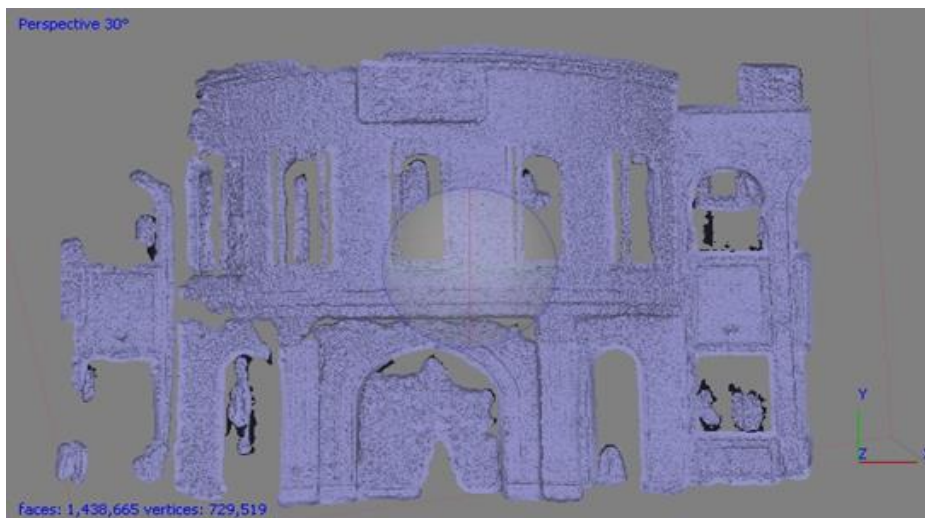

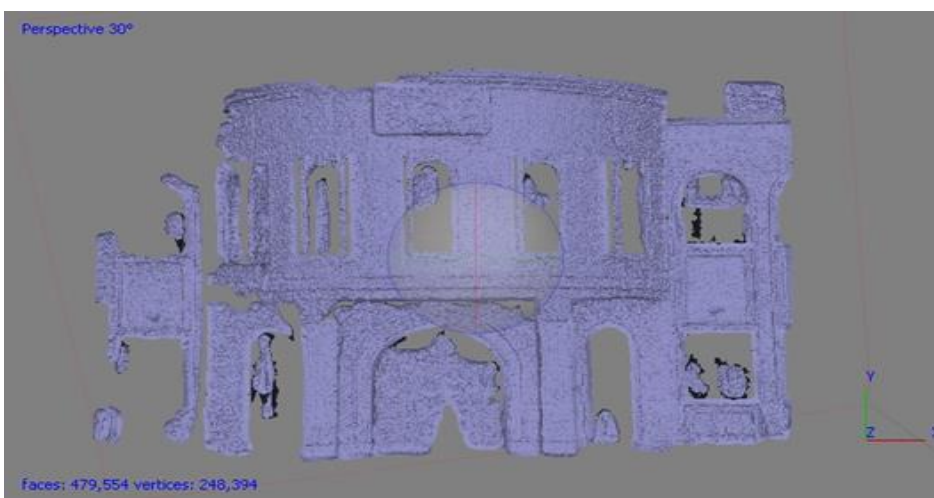Fig 16:- Build Mesh process with Surface Count: High setting. The total face count is 1,438,665.

Fig 17:- Build Mesh process with Surface Count: Medium setting. The total face count is 479,554.
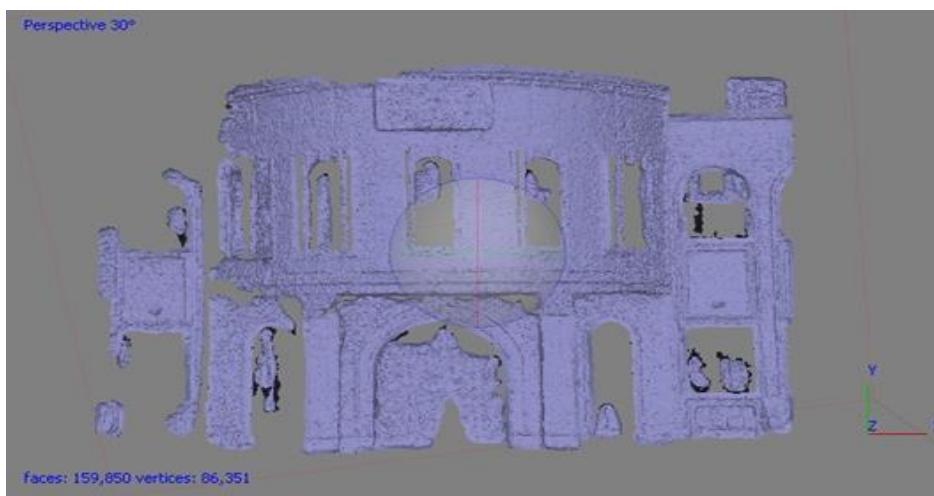

Fig 18:- Build Mesh process with Surface Count: Medium setting. The total face count is 159,850.

Another sub-setting is *Interpolation*. This sub-setting has three options: *Disabled, Enabled* (default), and *Extrapolated*. Disabled accurately rebuilds meshes depending on point clouds (Fig. 18). Alternatively, Enabled measures a certain diameter from each point and generates meshes as if the discrete points were found within the diameter; in one word, it automatically fulls small holes(Fig. 19).

Extrapolated generates meshes between discrete points and speedily fills holes, included large holes (Fig. 20). So, if the aim of a Photogrammetry project is to obtain accurate, the Disabled Interpolation setting is the best. On the other side, when visualization is the purpose of the Photogrammetric modeling, Enabled is the preferable.
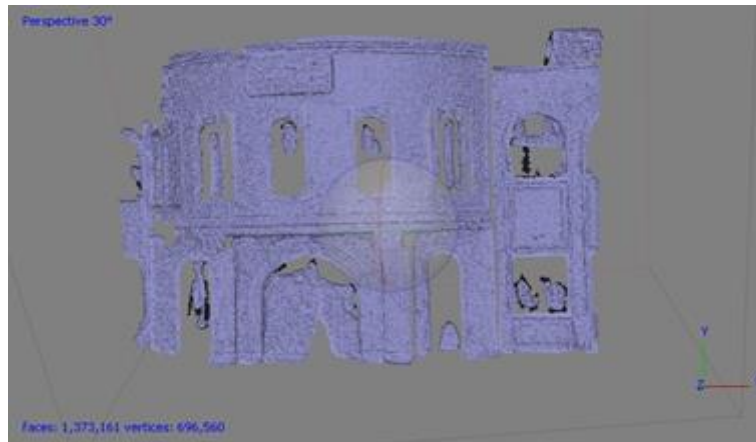
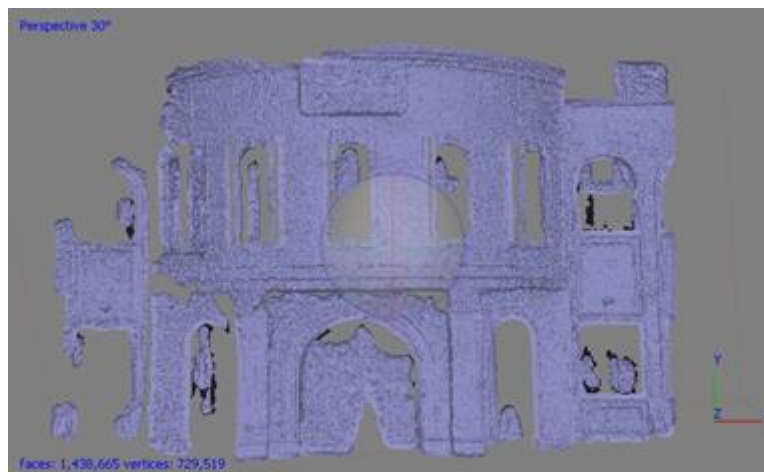Fig 19:- Build Mesh process with Interpolation: Disabled setting.

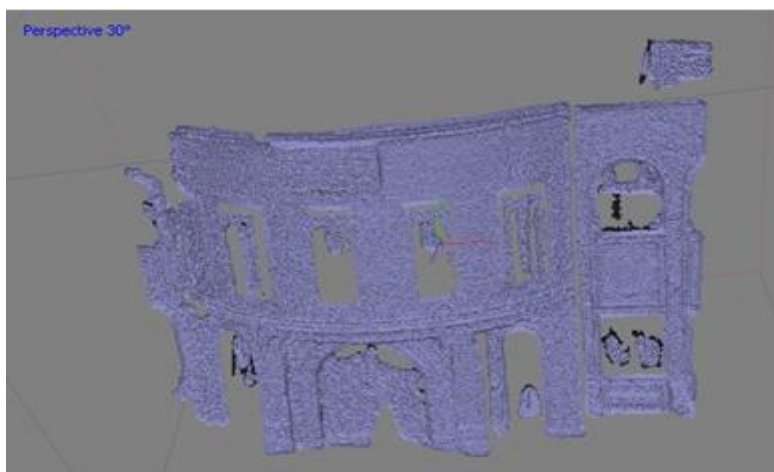Fig 20:- Build Mesh process by Interpolation: Enabled setting.

Fig 21:- Build Mesh process with Interpolation: Extrapolated setting.

The Point Classes are the last sub-setting. This sub-setting is for GIS-based mapping program; it permits to import point cloud from mapping software. They can be assorted into various categories, such as Building, Vegetation, Ground , Water, etc. This sub-setting permits Agisoft to read the categories assigned by GIS mapping software, and then generate meshes of selected point types.

VIII. BUILDING TEXTURE

The next step of the workflow is Build Texture. In this process, Agisoft generates a texture and places it on the surface of the meshes. The first sub-setting is Mapping Mode; this sets methods of UV mapping of generating textures. UV mapping generates a 2D atlas, or a canvas on which textures can be projected. Options for the Mapping Mode sub-setting are Generic, Adaptive Orthophoto, Orthophoto, Spherical, Single Camera, and Keep UV. The default setting is Generic; in this option, Agisoft automatically selects the best photos (depending on cubic projection) and forms a UV of meshes into texture atlases so as to transform the 3D structure of meshes into a 2D image format for generating textures. This mode is preferable for more sophisticated models that have 3D structures . Orthophoto generates a photomosaic from a projection plane and projects a generates photomosaic onto the meshes.

In another way which used by Orthophoto, the Adaptive Orthophoto discovers vertical faces and generates textures independently for those side meshes. Spherical mode generates a UV map for ball-like, spherical bodies. A texture is a 2D plane; so, Texturing a spherical form needs a unique mapping projection. However, this mode is only appropriate for spherical structures. Single image generates texture depending on one image; an image can be selected from any image in the active Chunk. Keep UV is for importing a UV map generated in various software. Many modeling programs permit to create the texture on meshes. Blending mode is another Sub-setting. To illustrate, Mapping Mode is applied to form UV maps, and Blending mode is applied to form chose photo-images on generating UV maps as textures. Blending mode has five options: Mosaic, Average, Max Intensity, Min Intensity, and Disabled.

The Mosaic option is the default blending mode. This setting chooses the closest image to corresponding surfaces and uses that image without blending with other overlapping images. The Average sub-setting computes an average pixel value, or the RGB value of colors, of overlapping images and uses those pixel values as textures. The Max Intensity setting applies images that have maximum intensity, or bright pixels, to corresponding surfaces. The Min Intensity setting is an inverse of the Max Intensity setting; it uses minimum intensity images. The Disable setting is, still, for imported models that usually have appropriate textures. In closing, depending on the author's experiences, Mosaic provides the best result between those sub-settings; so, Mosaic is preferable for generating textures on most Photogrammetric models.

Fig 22:- Build Texture process with Blending Mode: Mosaic setting.

IX. BUILDING DEM

It's an important step for generating an Orthomosaic, which allows Agisoft to produce a Digital Elevation Model. These values appear as a surface of a neat grid of elevation. DEM plays an important case in surface changes. Sparse point can be used to extract DEM, a dense points or a mesh. Depending on data of dense cloud more outcomes are computed. There are four parameters that effects on Build DEM, the first is *projection-type* this parameter divided into three sub-setting, *Geographic* - permits to select a geographic system with available options or load parameters of a modified geographical system. The coordinates system already selected for the model itself is by default takes The coordinates system. It can be changed to another one, as long as datum parameters can be obtained. *Planar projection-type*, Agifoft permits to the user put DEM on a plane. Projection plane and orientation can be chosen during create DEM. By a group of markers, it's possible to specify the plane. For example, to create DEM for project interested with facades perhaps use Planar projection-type. *Cylindrical projection-type*, permits to build DEM on a surface of cylindrical shape. In this state the value of height is

computed as the measure between the model to the cylindric surface.

The second parameter is *Source data*, It is computed DEM depending on dense cloud data. Elevation data results can be created from a sparse point, averting Dense Building step to avoid losing time.

The third parameter is *Interpolation*, If it is Disabled it's getting an accurate outcome because of the regions in order to dense cloud points are rebuilt. By Enabled (default) mode: Agisoft will compute elevations for all regions that appear in photos. The Agisoft software creates a solid sample with several elevation data in Extrapolated mode.

The fourth effect is *Point Classes* permits to choose a class or classes for generating DEM. An actual resolution of ground for DEM evaluated by the source data displays by the resolution value.
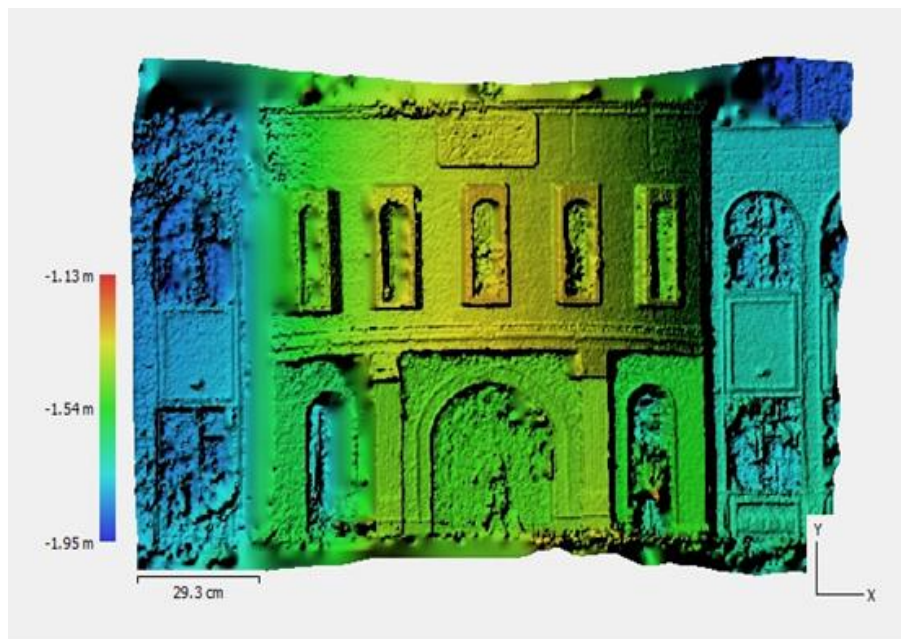

Fig 23:- Build DEM.

X. BUILDING ORTHOMOSAIC

It is the last step after building the model in which the coordinates (x, y, z) can be obtained anywhere in the model. An orthomosaic, also known as an orthophoto, is a photo of a region, collected of multiple photos stitched together using Photogrammetry, which has been corrected and scaled for accuracy. Generally, orthomosaics are of much better resolution and detail than satellite imagery of the same region, that reason for the use of high-resolution cameras at a comparatively closer distance from the ground.

There are two groups of parameters that affect on building orthomosaic, the first group is *color calibration*, the first one of color calibration is *Source data* that deal with which type of data that consider a basis for estimation of overlapping regions. It is favored to choose the type of source data depending on the surface that the orthomosaic on. This parameter divided into *Sparse cloud*: the assessment of the rough. *Model* illustrates more accurate outcome, but only in the case of sufficient details of the surface. DEM is a substitution of value of Model for the great data group when it is impossible to rebuild a mesh. The second color calibration parameter is *Calibrate white balance* a further choice to be turned on if white balance was wanted.

The second groups of parameters that affect on Orthomosaic is detailed below:

➢ *Projection type*
- *Geographic* permits to select a geographic system with available options or load parameters of a modified geographical system. The coordinates system already selected for the model itself is by default takes The coordinates system. It can be changed to another one, as long as datum parameters can be obtained.
- *Planar*: Agifoft permits to the user put DEM on a plane. Projection plane and orientation can be chosen during create DEM. By a group of markers, it's possible to specify the plane. For example, to create DEM for project interested with facades perhaps use Planar projection-type.
- *Cylindrical*: permits to project orthomosaic on a cylindrical surface. It uses to avert severe distortions when projecting cylindrical objects, like round towers, tunnels, tubes etc.

➢ *Surface*
Orthomosaic generation depending on the data of the DEM is specially efficient for time saving on mesh creation step during aerial survey data processing scenarios. Alternatively, mesh surface type permits to generate orthomosaic for less common applications,like creation of

orthomosaic for models and frontispiece of the buildings that might not be indicated at all.

➢ *Blending mode*

There are three types of blending the first is **Mosaic** that determine the frequency fields where the highest frequency item founded along seam line. The second is **Average** that use the mean value of pixels. The third is **Disabled** that interested in the color of the pixel in images to rebuild the surface.

➢ *Pixel size*

The ground sampling resolution refers to the default value for pixel size. The value of pixel size can be used in meter or in other units.

➢ *Max. Dimension (pix)*

The greater dimension of raster data can be set by this parameter.

➢ *Back face culling*

Projection of regions can be ignored on the surface where directed the counter of normals to the targeted projection plane. Where surface data are available, the Agisoft creates orthomosaic for the total area.
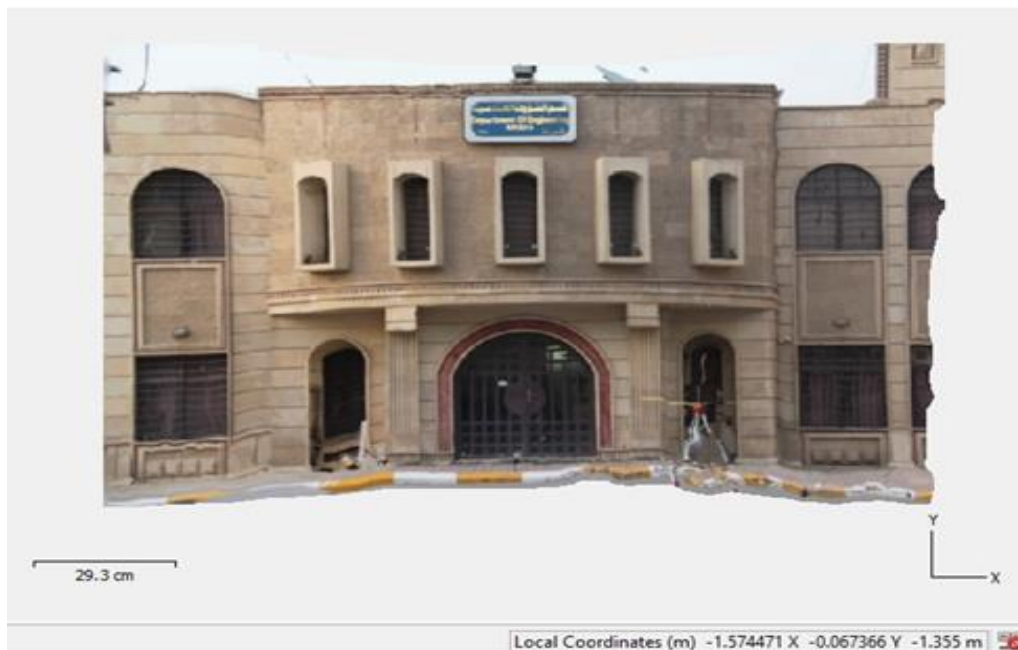

Fig 24:- Build Orthomosaic

XI. NEXT STEPS AND ADDITIONAL OPTIONS

There are more additional procedures that can take to improve the model.

Partial Save

Building 3D models take more time may be reach 4-6 hours when hundreds images are used in every process, sometimes cannot complete the work simultaneously so Agisoft permits to save the work partially.

Model scaling

The scale adds manually, When that can see the same points at least from three images, this helps to add a scale, by putting points called markers then compute the distance between the points.

Exporting the Model

For exporting any model after finishing it, there are different type of formats for display or importing such as Autodesk, VRML: This format allows you to work with the MATLAB environment, and more than 10 formats to use.

XII. CONCLUSION

This paper submits two main reasons to reach precise results: the first is the accuracy of the camera, where all its accuracy was better, the results were more accurate, and the second reason is the test of sub-setting lists that affect on the number of points of auto-matching where the more points the more dense will be better and therefore the mesh is better and the end result is the best.

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