

# ON THE USE OF LOW-COST SYNTHETIC MODELS FOR EDUCATIONAL AND RESEARCH PURPOSES IN DIGITAL PHOTOGRAMMETRY

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### ABSTRACT:

The appearing in last decades of new photogrammetric methods requires arranging new tools and teaching methods for education in Photogrammetry. Students can attain the desired objectives through the analysis of actual problems (project based learning). This approach to the reality can be reached from the resolution of actual projects similar to those developed at the commercial companies, whose input information usually will be aerial images. This type of projects have high costs associated (flight execution, ground control point measurement, quality control of the generated products) that make impossible to test several project configurations. At the University of Jaen a solution based in the synthetic scaled models has been adopted. The solution presented in this work makes enable the entire project development (both photogrammetric and LIDAR projects): planning; image capture; triangulation; and product generation (digital elevation model, stereoplottting, orthoprojection, etc.). It is important to point out that the application of this kind of model is not limited to the educational purposes. Thus this scaled model is usually used for research purposes for development of methods and algorithm debugging thanks to the no-cost images availability and the facilities to obtain terrain information.

## 1. INTRODUCTION

In the field of teaching and research it is necessary an approach to both the photogrammetric process and the different technologies that take part on such process. It is not easy in Photogrammetry to tackle successfully with the students the whole photogrammetric process from the flight mission planning and execution, data reduction and final product generation phase. The complexity is larger if several conditions have to be taken into account such as different scales or camera, flight height restrictions, block geometry, variety of final products (for example, orthorectification in urban or rural areas), etc.

Obviously, the task where there is a more limited accessibility for students is the flight mission and aerial data acquisition. The proposed methodology of this paper is based on simulated flight projects from scale models. This approach allows the students suggest (and carry out) a wide variety of solutions for different initial conditions usually given in actual projects, but at very low costs. A large variety of options can be easily explored: flight height, scale, camera and lenses, different overlaps (both end and side laps), control point network distribution, occlusion problems, integration of LIDAR data, etc. For sure proposing all these questions in actual projects are financially unfeasible for a lot of university departments.

The solution presented in this work makes enable the entire project development from planning and image capture, triangulation to product generation (digital elevation model, stereoplottting, orthoprojection, etc.). The use of synthetic models for the analysis of complex processes (for example, true orthoimage generation) has been used in Photogrammetry (Wolf, 2005; Albertz and Wolf, 2004).

Several scale models were designed and implemented in order to be used in the practical lessons of several courses given at the University of Jaen such as Elements of Photogrammetry, Analytical Photogrammetry, Digital Photogrammetry, Aerial Triangulation and Close-Range Photogrammetry. These courses can be followed by undergraduate students in Surveying Engineering (BS-Level) and Geodetic and Cartographic Engineering (Master Level).

## 2. MATERIALS AND METHODS.

### 2.1 Selected models

After previous analysis of different cameras and lenses, available workspace, working scales, etc., it was decided the elaboration of a wide variety of elements for the scale models: building with different heights, surfaces, roof shapes –flat, gabled, hiped-, etc.), vegetation and the topographical surface (the relief has been incorporated by contour levels). Figure 1 shows an overall view of one of the constructed scale models. The size of this model was 1.5x1.0 m, in order to obtain images blocks large enough to look actual cases as regards the number of images, end and side laps, flight scale, lenses, etc.

The area of this scale model represents an actual zone near Madrid (Spain) where there was available LIDAR data. The scale model was derived from the digital surface model (DSM) which in turn had been generated from the original digital terrain model (MDT) by removing buildings and vegetation. The construction of the terrain scale model was facilitated by plotting the MDS with a contour interval of 3 m (Figure 2). The model was constructed in plywood. The selected thickness of

the plywood sheets were 3 mm, so each sheet corresponded to a contour level.



Figure 1. Overall view of the scale model

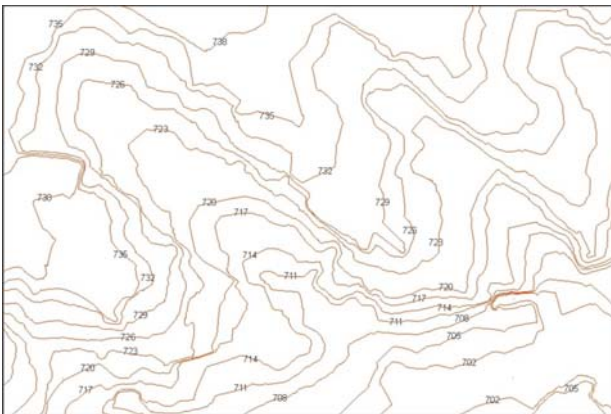


Figure 2. Selected area for the terrain of the scale model.

On the other hand, the buildings were constructed at different scales and shapes with wood bars. These buildings can be placed with different arranging, orientation, grouped or isolated houses, etc. Buildings were fixed with double-side adhesive tape. Vegetation was simulated with different materials (natural small branches with or without leaves, plastic and paper) and it was placed with putty at several positions (grouped or isolated, near building causing occlusions at walls, etc.). Figure 3 shows detailed views of the scale model with buildings and vegetation. These building and vegetation models allow the generation of a large variety of urban scenes, either on the terrain scale model (with contours) or on any available surface.

## 2.2 Camera and 3D laser scanner.

For image acquisition a digital SLR non metric camera Canon Eos D5 was employed (Figure 4). The image pick-up device used in the EOS D5 is a 12.8 million pixels CMOS sensor with noise reduction functions. Effective pixels are 4368 x 2912 and sensor size is 35.8 x 23.9 mm, so it is a full frame camera compared with conventional 35 mm film camera format. The main reason for selecting this camera was to reproduce suitably the geometry of some airborne digital cameras such as Z/I DMC or Vexcel Ultracam (although obviously not the resolution and quality of the acquired image). Moreover there were available different lenses (20, 24, 35, 50 and 135 mm), so

it was possible to select several geometries according to the simulated flight mission. For the scale model of figures 1 and 2, the camera was equipped with a Canon EF 35 mm 1:2 lens, which reproduced an adequate field of view for that work (field of view: 42° horizontal, 60° vertical in portrait mode).



Figure 3. Detailed views of some of scale models with or without simulated terrain.

Also a 3D laser scanner Minolta VI-Minolta (Figure 4) was used in order to simulate an airborne LIDAR above the scale models. This equipment allowed acquiring data with these characteristics: 307.200 points/scan; scanner-object distances between 0.6 and 1.2 m; scanned surface from 111 x 84 mm to 1300x 1100 mm; and a resolution of 0.17 mm in xy and 0.047 mm in z.



Figure 4. Canon D5 digital camera and 3D laser scanner Minolta VI-900

### 2.3 Camera calibration and control point network

Since the Canon D5 camera is a non metric camera, it had to be previously calibrated. So the method of selfcalibration was applied according to Cardenal et al. (2004). For the selfcalibration process a convergent photo-block around the model was performed (Figure 5). This convergent block was carried out before buildings and vegetation were attached to avoid occlusion of measuring points (targets). The lens was set in manual focusing at 1 m and the focus ring was fastened with adhesive tape to avoid variations in the camera inner geometry during the data acquisition. This distance was going to be the object-camera distance in the following examples. After images were taken, targets were measured. These targets (Figure 6) were going to be the control/check point network for the orientation of the simulated flights. The convergent block was adjusted in a free network adjustment with minimal inner constraints (without control points). The computed inner parameters of the 35 mm lens at the calibrated distance are in Table 1.

<b>Calibrated principal length (at 1.0 m)</b>	
f = 36.317 mm	
<b>Principal point offset</b>	
x <sub>0</sub> = 0.100 mm	y <sub>0</sub> = 0.208 mm
<b>Radial distortion coefficients (distortion model of SO CET SET 5.3)</b>	
k <sub>0</sub> = 1.383514e-003	k <sub>1</sub> = -8.612034e-005
k <sub>2</sub> = 8.622483e-008	k <sub>3</sub> = 0.0

Table 1. Inner orientation parameters of Canon EF 35 mm lens (lens focused at 1 m)

After the selfcalibration process, the computed spatial coordinates of targets were adjusted in scale by measuring accurately some distance between targets. These adjusted spatial coordinates (a total of 58 points) define the final control/check point network (scale model reference coordinate system).

### 3. SIMULATION OF PHOTOGRAMMETRIC FLIGHT

After selfcalibration and control point calculation, building and vegetation were placed with different usual arranging in urban areas. Next the flight was simulated following a previous

planning. Table 2 shows the characteristics of one of the simulated flights: 90 images distributed in 4 strips.



Figure 5. Some photographs of the convergent photo-block for selfcalibration and control/check point network definition.

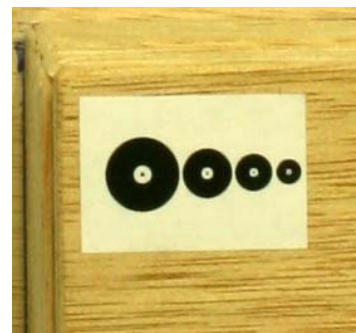


Figure 6. Detail of the target design for control/check points network. Different sizes allow working at different scales. The annular design also allows methods for automatic point measuring.

The “flight” was simulated by hanging the scale model vertically on the wall and images were taken with the help of a tripod and a measuring tape at the planned poses. Since images at the block edges (strips 1 and 4 and initial/end images of the strips) had imaged large areas of the wall outside the scale model, some targets had to be placed around the model to be used as tie points. Figure 7 shows details about the data acquisition process.

Camera data	
Camera	CANON D5
Focal length	35 mm
Format	23.9 x 35.8 mm
Image size	2919 x 4368 p
Pixel size (mean)	0.008 mm
"Flight" data	
Distance	1.0 m (aprox.)
GSD	0.23 mm
Size	682.8 x 1022.8 mm
End-Side Laps	90 - 60%
Photographic base	68.28 mm.
Distances between strips	409.1 mm

Table 2. Main characteristics of a simulated flight.



Figure 7. Simulation of photogrammetric flight

After image acquisition, all data (inner parameters, initial approximations to exterior parameters and control/check points) were processed and the block was oriented with conventional digital aerotriangulation methods (automatic point measurement and bundle adjustment) with BAE Systems SOCET SET® v.5.3. Final orientation errors were 0.189 pixels in the image coordinate system and in object (scale model) space were 0.269 mm, 0.367 mm and 0.359 mm (as rms), in X, Y and Z (respectively) and the global error was 0.580mm.

#### 4. SIMULATION OF LIDAR

Also, a digital surface model was obtained from a close range 3D laser scanner Minolta VI-900. The merging and referencing of the point clouds to the scale model system was done with the software I-Site Studio v.3.0. With this procedure the data from an aerial LIDAR sensor was simulated.

##### 4.1 Selection of scan stations.

In planning the different scan station poses some factors were taken into account: all the working area (the area of the model) had to be measured without occlusions; the final number of scan stations had to be fewer as possible; and the final point cloud density required had to be reached.

Since the minimum density planned was 1 mm and bearing in mind the scale model size and the technical characteristic of the scanner, several scan stations were planned. And, because the scanning process was static, there were hidden areas from all scan stations. That implied additional scan stations. So 3 strips were planned with 5 scan stations per strip. The overlaps (both end and side laps) were near 50%. Figure 8 shows the process of scanning and some examples.

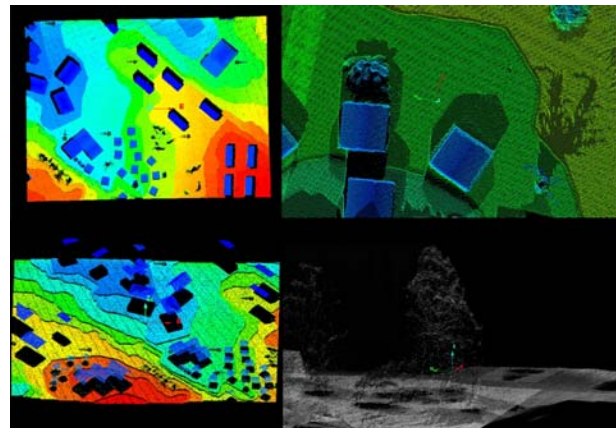


Figure 8. Upper: scan process. Lower left: zenith and perspective views of a single scan; Lower right: detail views (buildings and vegetation).

##### 4.2 LIDAR data merging.

After scanning process was completed, all the point clouds from different scans were merged in a common coordinate system. The central scan station was considered as reference station and the rest of scans were merged by surface correlation with I-Site Studio software. The merging process and final result is shown in Figure 9.

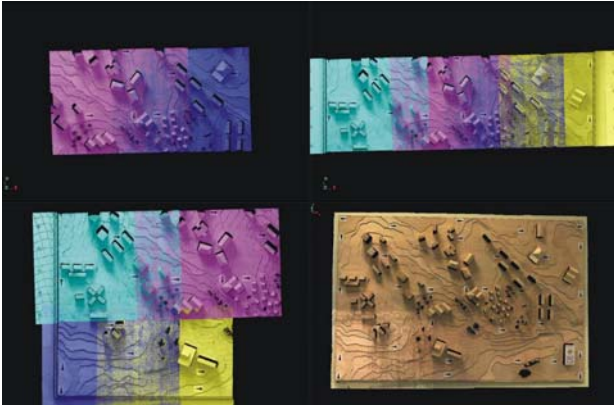


Figure 9. Merging of single scans. Strip formation. Strip connection. Final RGB model.

**4.3 LIDAR data referencing. Transformation of LIDAR data to scale model reference system.**

After merging all data, these data had to be referred to the final (scale model) reference system. So control points were measured on the surface (Figure 10) and a 3D transformation was performed. At this moment all data (photogrammetric and laser) were in the same reference system.

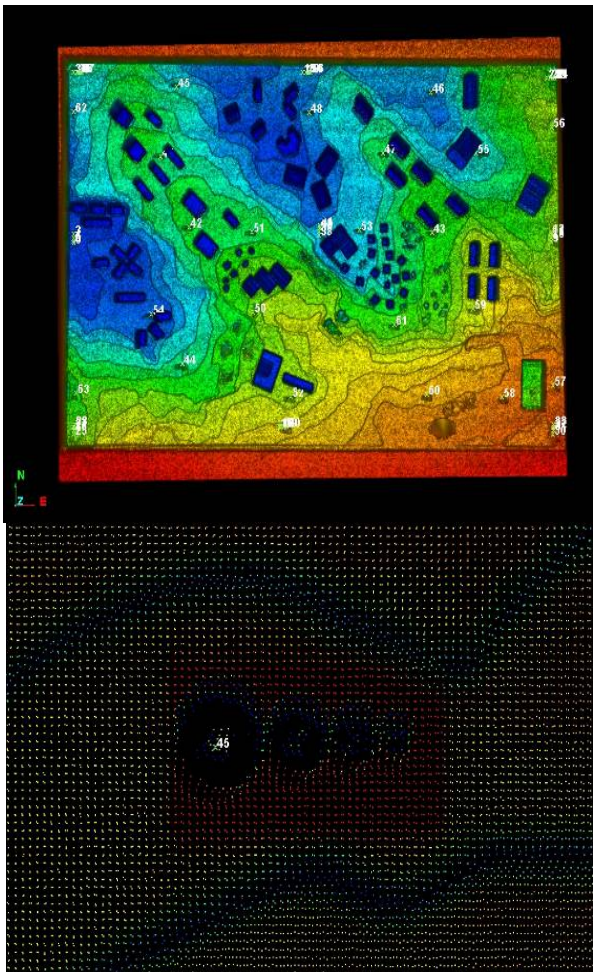


Figure 10. View of control points

**5. APPLICATIONS AND PRODUCTS**

The last stage of this work is the generation of cartographic products derived from the acquired and processed data. Obviously, the application fields and final products will depend on the planned objectives of the lecturer or researcher. Two examples are illustrated.

The first one is the generation of true orthos in urban areas. With respect to teaching, a complex photogrammetric process like true ortho generation is presented to the students. With respect to researching it is important the developing and debugging of the appropriate algorithms. Figure 11 shows an example of the different stages for true ortho generation. The developed algorithms have been successfully employed in the Research Project DATOS (*Development of an integrated system of true-ortho rectification*; Antequera et al., 2008).

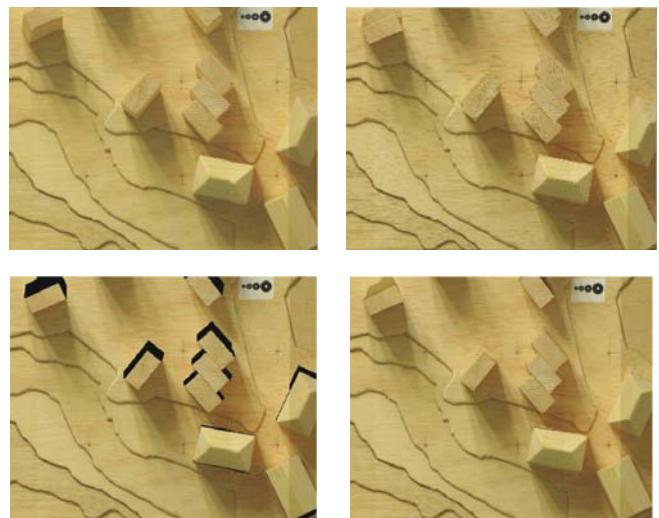


Figure 11. True ortho generation. Upper left: Orthorectification with DTM. Upper right: Orthorectification with DSM. Lower left: Occlusions finding. Lower right: Restoration of occluded areas.

The second example is related to the generation of complex products where it is necessary to simplify (and control) the contouring conditions. They are processes of automatic feature extraction from photogrammetric images and the obtained DSM from LIDAR. Figure 12 shows the results from a method proposed in Perez-Garcia and Delgado (2004) for automatic building extraction and classification. These results have been possible with this methodology (working with scale models) and the parallel development of the computing programs (Perez-Garcia et al., 2008).

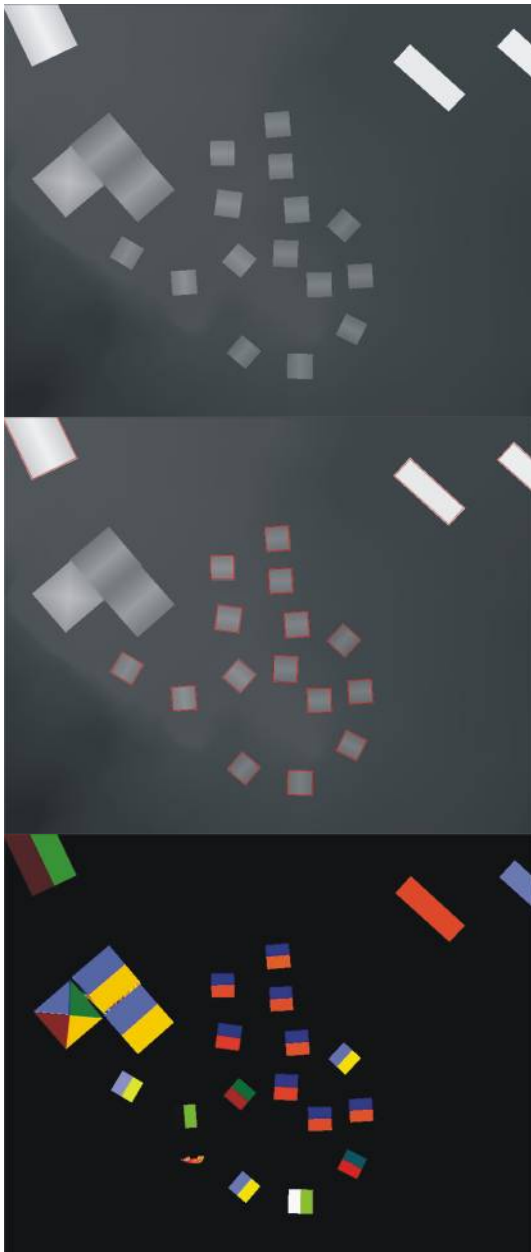


Figure 12. Automatic extraction of buildings. Upper: DSM; Centre: rectangular representation of the buildings; Lower: Analysis and classification according the shape and orientation of roofs.

## 6. CONCLUSIONS

In this work the possibilities of using scale models in the fields of teaching and research in Photogrammetry are presented. With respect to teaching the employment of scale models allows the students a direct contact with the photogrammetric process as a whole, from image acquisition (with different configuration respect to overlaps, photo-scales, etc.), non metric camera calibration, image orientation (automatic digital aerotriangulation and bundle adjustment) and processes related to information extraction and orthorectification. And in the other hand, these tools are valuable for the development of new algorithms in aerial images processing (for example, application

of methods for true orthorectification) and treatment of LIDAR data in order to automate the processes.

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