Contributions to the OEEPE-Test on Automatic Orientation of Aerial Images, Task A - Experiences with AMOR

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1 Description of the methods and programs used

A program for the automatic exterior orientation called AMOR was developed by Wolfgang Schickler at the Institute of Photogrammetry, Bonn (Schickler 1994). The motivation for the development of AMOR was the change of the orthophoto production from an analytical to a digital system at the Landesvermessungsamt (State Survey Department) North-Rhine-Westfalia in Bonn. Details of this project can be found in (Läbe and Ellenbeck 1996). AMOR has been integrated into SOCET SET, the photogrammetric workstation software from Leica/Helava. For the test SOCET SET 3.1.3c was used as an environment for image handling, interior orientation and the measurement of the check points. The integrated version of AMOR was used for the orientation process. The next paragraphs describe the methods and ideas used in AMOR.

1.1 Principal idea of AMOR

AMOR is a shortcut for 'A'utomatic 'M'odel-based 'OR'ientation. The principal idea of the algorithm is finding 3D-edges in the image to be oriented. In most cases one wants to use a set of 3D-edges as ground control for many aerial photographs taken at different times or seasons. Because of this the 3D-edges have to be time invariant. Edges at big roads or buildings are such structures. Up to now we used 3D-wireframe models of buildings as 3D-edges, but in this test we have also used road features. One set of 3D-edges which are close together builds a *control point model*, which plays the role of a single control point in the manual estimation of the exterior orientation parameters. A database of such control point models is required. This database was generated from the vector data available in the test.

1.2 AMOR in detail

To understand the requirements for the database, a closer look at AMOR is helpful. AMOR consists of the following steps (see figure 1):

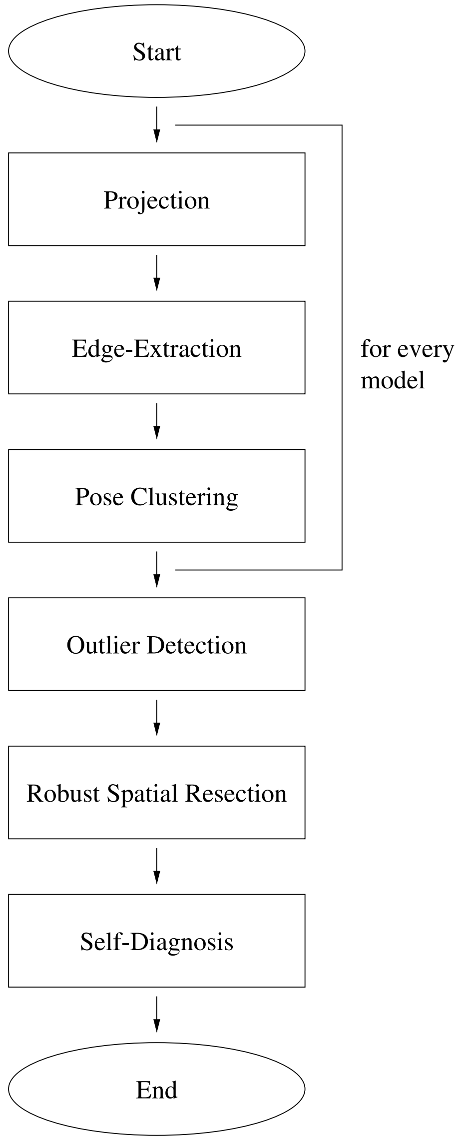

Figure 1: Flowchart of AMOR

- **Projection** of the 3-D control point model onto the aerial image using the approximate orientation values. From the approximate orientation values one can derive information as to which control point model is in the image, its approximate location (200 pixel for example) and the approximate perspective (up to a few degrees) of the control point building in the image. This projection leads to a 2-D wireframe control point model in the sensor system.

- **Extraction** of straight line segments in a subsection of the digital aerial image. The position of these subsections with respect to the whole image is derived from the first step. Its size depends on the precision of the approximate orientation values and the size of the control point model in the image.

- **Pose Clustering** to determine the approximate position of the control point model in the subsection of the aerial image. This 2-D matching procedure leads to a preliminary set of matching candidates between image and model edges. Here *translations* of the projected control point models are estimated.

- **Outlier Detection** technique using a RANSAC procedure to find incorrectly located control point models and to predict a more likely set of matching candidates if necessary and determination of parameters of the exterior orientation for the next step.

- **Robust Spatial Resection** using homologous line segments to clean the whole set of preliminary correspondences. This 3-D matching procedure is the final common fit of the 3-D control point models to the image.

- **Self-diagnosis** by analyzing the final result with respect to precision and sensitivity considering the geometric configuration of the control point models. This enables AMOR to decide whether the automatically determined orientation parameters are acceptable or have to be rejected.

1.3 A closer look to the estimation of the orientation parameters

The capability of AMOR for the estimation of the different orientation parameters varies. The approximate orientation values for the flying height Z and the rotation κ around the Z-Axis should be "more accurate" than for X, Y, ω and ϕ. The reason for this general statement is the search strategy used.

The important matching step is the pose clustering where *two translation parameters* x and y of the projected control point models in the image coordinate system are computed. So a shift in X- and Y-direction of the projection center is being observed "directly" in this search procedure. For ω and ϕ an angle of 0 degrees as an approximate value is sufficient in nearly all cases of aerial images.

To match the projected 3D-edges in the images the direction of the projected 3D-edges and the image edges is used as a criterion. So the approximate value of κ has to be good enough. For the approximate determination of κ a procedure, which uses the differences of the main directions of the projected control point models and the main directions of the image edges in the search areas, may be suitable for urban regions. Such a procedure has not been implemented for AMOR.

Large scale differences of the projected ground control point models and the image edges make a match of the whole model impossible. Scale independent models, e.g. of roads, are conceivable but this type of model is rare and not very advantageous for the current matching task. Therefore the approximate value for Z has to be good enough for the matching step. To get a more scale independent orientation procedure it may be suitable to change the pose clustering step. Here not only a translation, but also a scale and a rotation parameter could be estimated, as described in (Stockman 1987).

2 Work flow used for the test

2.1 New Problems

AMOR had not been tested on large scale aerial photographs and new problems to be solved arose. The following table gives an overview.

Problem	Solution
search area too large in original image	using other pyramid levels
buildings are too detailed with not enough long edges in the higher pyramid levels	using roads as control features
road features may have only one direction and therefore cannot be localized on 2 dimensions	using only roads with edges which covers a large number of directions (road crossings)

2.2 The approximate orientation values

For projection center approximate values were given. For ω and ϕ the approximate values were set at 0 degrees. In general κ can have all possible values, depending on the flight direction. For the test an angle of 0 degrees was assumed.

A first test showed that the given flying height was not accurate enough so that the scale of the models is not good enough for matches especially in higher image pyramid levels. Here a manual adjustment of the approximate value was done.

2.3 The vector data

The vector data delivered within the test material had to be converted into a control point model database for AMOR. Because the control point models should be equally distributed in the area covered by the images, an X-Y-grid was laid over the database. At every grid point in a certain search radius polygons of buildings roofs (type no. 41 in the vector data) or road polygons (type no. 318) were used. In the case of roads an additional test of the angles between the edges was performed to make sure that there are enough directions of edges in the control point model. For this step a C++ program was written. No manual editing of the resulting control point model database was done.

For the buildings a grid width of 200 meters and a search radius of 25 meters was used. For the roads the grid width was 100m and the search radius 45m.

2.4 Final work flow

These considerations result in the following work flow used for the orientation of the images:

1. Set up a database of control point models of buildings from the map data.
2. Set up a database of control point models of roads with many directions of edges from the map data.
3. Manual improvement of the flying height by using the differences in scale between the projected control point models and the image. The approximate orientation value for Z was set from 780m to 700m.
4. Use of AMOR on pyramid level 1:8[1] with road crossings and a search area of 100x100 meter on the ground to get a better κ. This was done only for image 3308. AMOR

[1]number of columns and rows in this level is 1/8 of the original image

does not end successfully but with better approximation values for κ. 14 control point models where used. For the next steps the results of AMOR of the higher pyramid levels were used as approximations.

5. Use of AMOR on pyramid level 1:4 with road crossings and a search area of 100x100 meter on the ground. 14 (image 3308) and 13 (image 3309) control point models were used.
6. Use of AMOR on pyramid level 1:2 with buildings with a search area of 20x20 meter on the ground. 13 (image 3308) and 15 (image 3309) control point models were used.
7. Use of AMOR on pyramid level 1:1 with buildings and a search area of 4x4 meter on the ground. The same models as in step 6 were used.

3 Derived data

3.1 Orientation data

The final derived orientation data for the images are:

image 3308:

parameter	value (in meter or gon)
Y(Northing)	289866.76
X(Westing)	235212.75
Z	714.31
ω	2.07729
ϕ	1.45913
κ	-3.53579

image 3309:

parameter	value (in meter or gon)
Y(Northing)	290282.78
X(Westing)	235206.20
Z	708.53
ω	3.32697
ϕ	-0.36797
κ	-2.71773

3.2 Coordinates of the checkpoints

The coordinates of the checkpoints are measured manually in the oriented images with the control-point-editor-tool of SOCET SET. In the photogrammetric model no Y-parallax greater than one pixel could be observed. The measured coordinates of the checkpoints are:

point number	Y(Northing)	X(Westing)	Z
635	290030.98	235107.61	27.56
145	290108.28	235256.57	23.89
40	290202.14	235381.48	19.38
770	290344.16	235318.96	19.87
645	290327.73	235620.98	12.05
365	290194.34	235595.51	12.20
340	289986.02	235564.48	20.11
205	289798.41	235616.61	19.79
605	289854.35	235727.70	15.83
641	289999.90	235752.10	17.19
60	290170.42	235667.00	12.20
172	290303.18	235721.19	10.20
250	289970.02	235383.28	24.57
620	289844.07	235432.90	24.04
695	289842.07	235294.46	25.10
790	289949.38	235281.49	26.31
745	289815.03	235115.14	34.33
211	289875.89	234933.66	34.59
572	289887.06	234874.40	35.00
391	289920.92	234802.14	32.62
610	290064.81	234811.06	32.92
235	290017.80	234898.37	31.67
50	290181.68	234894.53	29.67
5	290195.67	234809.93	30.61
160	290253.11	234898.58	32.05
370	290117.09	235061.78	26.19
500	290236.96	235125.33	23.20
260	290312.52	235210.78	23.88

4 Suggestions for improvement of the orientation process

To make the determination of the exterior orientation parameters more reliable and to increase the possibility to detect false orientation parameters by a self-diagnosis procedure, as implemented in AMOR, it is highly recommendable to use vector data which covers not only the overlapping part of a stereo model but the whole images. This recommendation may be important for all approaches which use single image orientation procedures. In the given vector data polygons were only found in the area of the photogrammetric model.

Because AMOR searches the edges of the vector data, for this algorithm it is necessary that the 3D-edges appear as 2D-edges in the images. This condition is not true if there are occlusions or generalizations. In the given map data base missing roof structures could be observed. Regarding the data of saddleback roofs for example, it appears that only one polygon at gutter height had been digitized. Here a real 3D acquisition would lead to more information for AMOR. Our experience is that in the case of a saddleback roof building the gable line is an important feature because this line is mostly visible in the images and has a high contrast. But this test shows that AMOR can work also successfully without complex roof structures.

In the case of a stereo pair as given in this test it would be a good idea to use an automated relative orientation to "connect" the two images. It may then be easier to find ground control features in the images because one could use the epipolar geometry constraints for this task. In contrast to that AMOR was developed for the orientation of single images. But it would also have been possible to combine a relative orientation with AMOR. Then only one of the two images would have had to be oriented with AMOR. The absolute orientation of the photogrammetric model could then be computed with the help of the exterior orientation parameters derived with the help of AMOR.

References

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