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Topographic References and Plotting

Introduction

Before starting a photogrammetric survey we need to know some ground points. There are many different ways of finding the position of these points: each way is differently precise and requires more or less difficult operations and resources. Here are some examples of different ways of preparing a topographic network of ground points and control points on earth, and at the end is shown an example of the network realized on the Jordanian territory which aimed at the orientation of satellite images and the plotting of aerial photographs.

Features of Ground and Control Points

Under "ground point" we understand those references taken from the ground and very visible on the (photographical or digital) image and which are used to make projective transformation or real plottings. Under "control point" we understand the comparison between the real position and those data obtained by rectifing the image or by plotting the survey in order to check the work carried out .

In both cases these points are known plano-altimetric points (i. e. taken from cartography); otherwise they can be obtained by a topographical survey.

The scale of photographs as well as the satellite image resolution are the presupposition for the precise determination of ground points. It is clear that photographs at a scale of 1:40.000, for instance, which can be used for survey at a scale of 1:10.000, will require preciser ground points than necessary in order to rectify a SPOT image with an average 10x10 m^2 pixel. Should digitized aerial photographs be used to improve their resolution, ground points will be related to the scale of the aerial photographs.

The number of ground points has to be fixed on the base of different principles whether it is a question of aerophotogrammetry or of satellite images. According to the rules of topography at least three ground points are required to realize the absolute orientation phase of a stereoscopic pattern. In case of many following patterns the technique of aerial triangulation enables the reduction of direct ground points. The processing of satellite images, according to the used algorithm, requires different numbers of ground points (usually fifteen). In both cases it is very important that the georeferenced processing is very precise as well as the measuring of ground points and their consequent localization. The validity of the metric information deriving from the image depends on this orientation phase as well as the reliability in searching particular elements from the ground during the post-interpretation.

As regards those points obtained from cartography we have to underline two aspects concerning the updating of the maps and the scale.

One usually has to use old maps which are very different from the actual territory. In this case we run the risk of making mistakes if the careful transformations have not changed so much those features that are usually used as references (for instance crossroads).

The points are read with the approximation determined by the scale: should a digitizer with a 0.1 mm resolution be used, the points will be read with the 2.5 mm approximation on a base of a scale of 1:25.000. The intrinsic error of the map, generally equal to 0.2 mm, will give precise points with a 5 m error, using a map at a scale of 1:25,000; that is a bearable value when using satellite images.

Should these ground points be used for photogrammetric plotting, such an approximation is no longer enough: we have to make use of ground points (for example trigonometric or cadastral points) or to prepare a network with vertexes suitably positioned in the area.

In conclusion the problems with map-making are as follows:

- updating
- intrinsic error
- availability of the required scale.

On the other hand we have the following advantages:

- immediate availability of information
- references for toponyms
- cheap method.

The survey is realized via topography. It can be carried out traditionally by means of optical-mechanic or electronic theodolites, total stations or GPS (Global Positioning System) receivers. The network must follow topographic criteria by trying, then, to put it into the cartographic reference system and also by realizing many different and various measurements in order to obtain the position of vertexes. The disadvantages of topography during surveying are:

- realization times that, sometimes, are quite long
- logistic problems such as moving from a control point to the next one, equipment and so on ....
- financial burden.

But we also have many advantages:

- choice of suitable points
- possibility of carrying out an accurate recognition on the ground
- precise ground points which can be defined before projecting.

Topographic Survey

Traditional topographic measurements make use of the classic survey method that is the intersection and the space resection, the trilateral measurement and the survey with the polar coordinates. The limits of these methodologies are well known: the biggest limit is the mutual visibility between station and collimated point.

Sometimes when the ground is hilly, it is difficult to find a suitable station point. In this case it is convenient to make use of the GPS (Global Positioning System): it is a survey technique that uses those signals transmitted by the NAVSTAR satellite network (consisting of about thirthy satellites) which are received and processed on earth. This method is quite simple also for non-experts: the receiver is positioned in the network vertex then it begins to receive signals for a period of time which has to be decided upon when planning, according to the displayed parameters.

The obtained data can be stored differently (memory card, hard disk) and stored later on so that the user can finally know the station point of the reference system WGS84.

This abbreviation means a precise reference surface, the geoid, and the coordinates refer to a geocentric cartesian tern. The big problem that the user usually has to face concerns the transformation of coordinates obtained with system WGS84 into coordinates referred to the used map-system.

The reference surface as well as the rototranslation have, then, to be changed, also by varying the scale, and related to the projection system.

This last operation is still possible if we know the coordinates (in the final reference system) of a convenient number of points.

The problem of adjusting the network also concerns the classic method of survey, that is when using ordinary equipment.

Plotting

The operations connected with territory surveying are usually carried out by aerial photogrammetry both for average and big areas. However, we take advantage of photogrammetry also on earth in other fields such as: architecture, industry, astronomy and many others. The used equipment is quite simple if we compare it with that one used for aerophotogrammetry, that is why this technique is broadly available to those who are not acquainted with photogrammetry.

As regards aerial photogrammetry the plotting of aerophotographs is usually carried out via analogical or digital operations, however, satellite images can also be applied to cartography at average and small scale. As regards terrestrial photogrammetry (also called "close-range") the plotting equipment is generally analytic, some models are very simple and cheap, and they can also be applied to archaeology.

By means of photogrammetry it is possible to obtain the following products: tridimensional scale drawing, section, retification, orthoprojection, a particularly complete information and metric product.

The working images are usually photographs taken with both metric and halfmetric aerial cameras or terrestrial cameras. These last ones in comparison with metric cameras are much easier to handle and cheaper also.

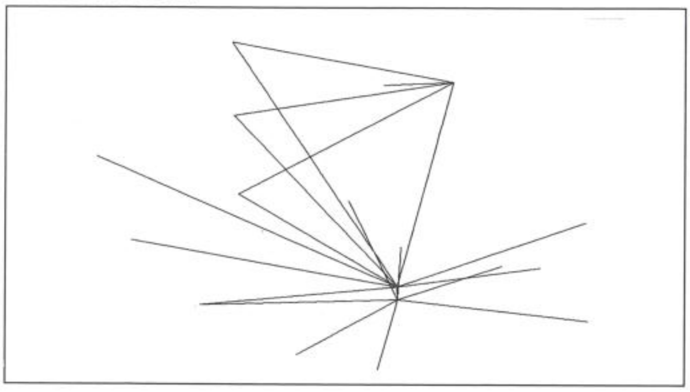
Photography is being changed from analytic into digital: this is quite a recent revolution of the photogrammetry survey. As a matter of fact, the used image is a digitized analogical image intended as a photograph or video signal coming from a video camera. The advantage is great: the user can decide at the very moment whether the image quality is good enough or the acquisition has to be repeated once again.

On the other hand, the limits of the resolution of the digital image still exist.

Recently, this sector has been growing very quickly and many manufacturing industries have already studied and launched, on the market, different products for the realization of both architectural survey (for example digital rectification and orthophotography) and territory survey (digital stereoplotter for aerophotogrammetry). Also, during plotting we need a series of ground points, conveniently distributed, which are used for the so-called "orientation" operation (we have already talked about the adopted choice criteria).

The Network of Jarash

This is to present an example of our recent realization of the topographic network which was carried out around Jarash in Jordan, in the district of ʻAjlūn. Our main purpose was to provide a series of ground and control points for the rectification of SPOT and LANDSAT TM images and the plotting of aerial photographs. The available cartography is at a scale of 1:50.000, updated in 1960, which does not suit our purpose. However, as we have already said, the network has to be related to a cartographic reference, because we have to use points, meant as vertexes, which can be easily read on the map, on the photographs and on satellite images. As there was not much time to realize the project, taking into consideration the orography of the country, we had to use the GPS technique for the topographic survey. One can see the structure of the network on (FIG. 1): many different directions start from the central core.



1. Network structure (Tetrapylon, Jarash).

The core has a fixed point, the centre of the South Tetrapylon of Jarash. We have chosen this point because it is easy to find on the map, even if only planimetrically.

As regards other points we found the most reliable crossroads, because they can be easily found on the map but are only visible on the digital image.

We needed to take five different measurements and made an 11 hours simultaneous acquisition: we could find the position of 18 vertexes by measuring 22 base lines (under base line we understand a segment, or, better, a vector whose extremes are the fixed station point of the reference receiver and the other changing station point).

The measurements have been carried out with the GPS Geotracer 2000 receiver and processed with the Geotracer Postprocessing Software. Our purposes have already been shown at the beginning when we also limited them to obtain the required precision.

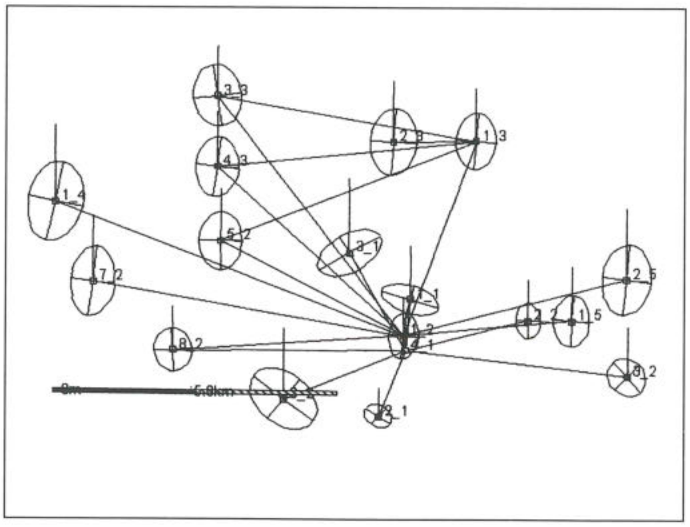
Starting from the features of the SPOT image and photographs we set a tolerance of 50 cm in the point position. At the end of the first (measurement) session we learnt the possible reception conditions and we fixed 30 minutes for each measurement. As we could dispose of no less than six satellites it has been possible to measure the base lines with average squared differences of about one centimetre (TABLE. 1) It was possible to improve the precision by longer observation times but, as was already said, there was not much time.

Table 1. Measurements of base lines.

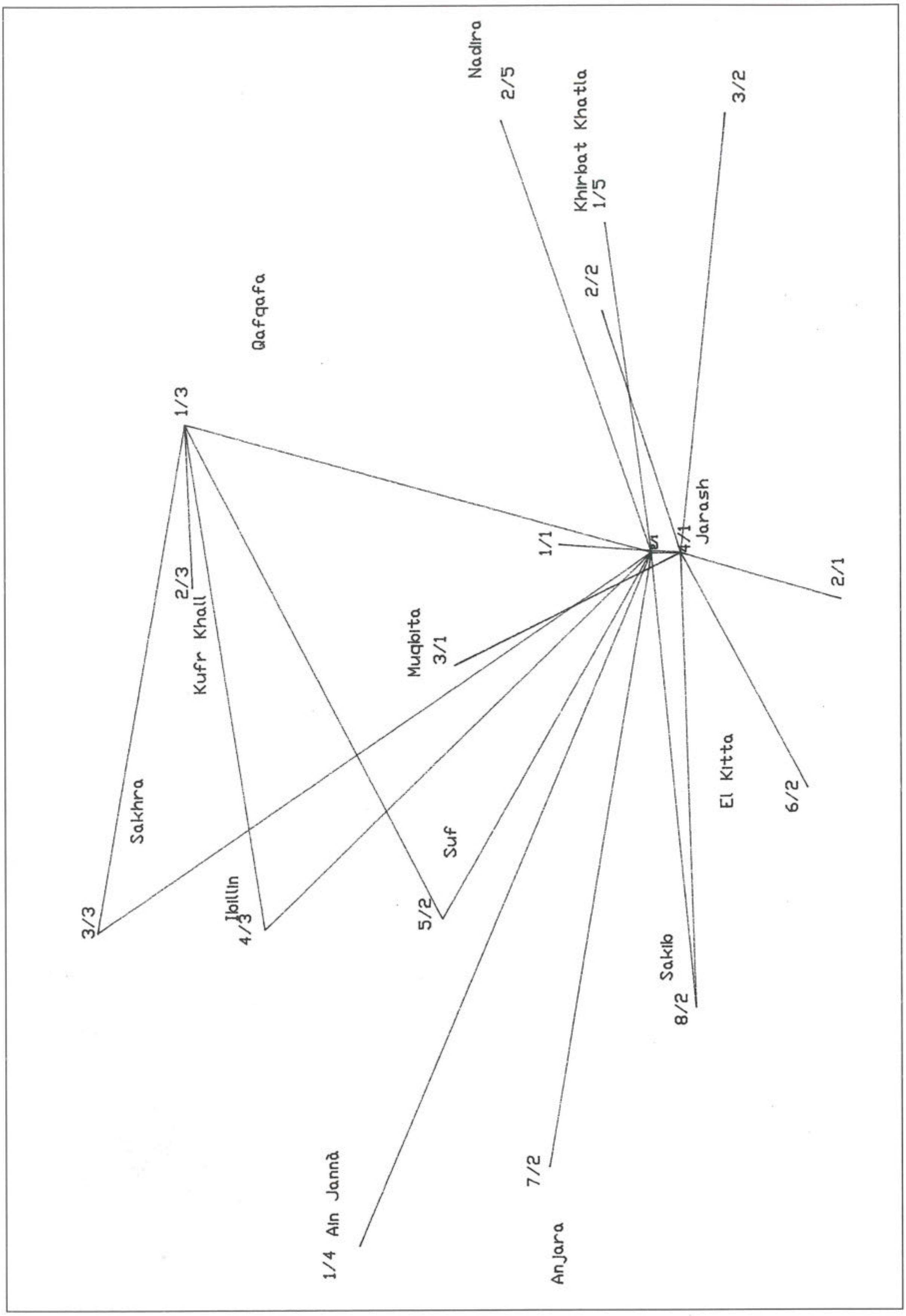
Baseline	σx	σy	σz
4_1/2_1	0.5	0.7	0.6
4_1/1_1	0.8	1.5	0.7
4_1/3_1	2.1	0.8	1.0
4_1/3_2	1.0	1.0	0.8
4_1/6_2	1.4	1.7	1.0
4_1/8_2	1.5	2.9	1.4
4_1/2_2	0.9	0.8	0.6
1_2/4_1	1.2	0.6	2.0
1_2/7_2	1.2	1.0	0.8
1_2/8_2	1.4	1.3	0.9
1_2/1_3	1.6	1.1	1.3
1_2/3_3	1.5	1.6	0.8
1_2/4_3	1.3	1.0	1.2
1_3/4_3	0.8	0.7	0.6
1_3/5_2	1.7	0.9	1.0
1_3/2_3	0.7	0.6	0.5
1_2/8_2	1.1	0.9	0.8
1_2/1_4	1.1	1.2	1.5
1_2/5_2	0.9	1.1	0.8
1_3/3_3	1.3	1.3	0.8
1_2/2_5	1.4	0.8	1.1
1_2/1_5	0.8	0.7	0.5

The acquired measurements have always been integrated with the equipped software: our results bear the greatest determination error of the coordinates of different vertexes which is less than half a metre, which is satisfactory (see FIG. 2).

In the light of the obtained data and our experience we can say that if we had used the classic topographic method we could not have measured such an extended area (about 300 km^2) with such an outstanding orography during such a short time and with so many points.



2. Coordinates of vertexes.



3. Plan of extended area using topographic references and plotting.