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WMA 314: SURVEYING AND PHOTOGRAMMETRY (3 Units)

Contouring: Characteristics of contours; methods of locating contours and plotting, area and volume. Construction survey general principles, setting and laying out Engineering structures, pipes and drains. Production, reading and interpretation of maps.

Basic Photogrammetry and practical uses of aerial photographs.

Photogrammetry is the technique of measuring objects (2D or 3D) from photo-grammes. We say commonly photographs, but it may be also imagery stored electronically on tape or disk taken by video or CCD cameras or radiation sensors such as scanners. The results can be:

- coordinates of the required object-points
- topographical and thematical maps
- and rectified photographs (orthophoto).

Its most important feature is the fact, that the objects are measured without being touched. Therefore, the term „remote sensing“ is used by some authors instead of „photogrammetry“. „Remote sensing“ is a rather young term, which was originally confined to working with aerial photographs and satellite images. Today, it includes also photogrammetry, although it is still associated rather with „image interpretation“.

Principally, photogrammetry can be divided into:

1. Depending on the lense-setting:
   - Far range photogrammetry (with camera distance setting to indefinite), and
   - Close range photogrammetry (with camera distance settings to finite values).
2. Another grouping can be
   - Aerial photogrammetry (which is mostly far range photogrammetry), and
   - Terrestrial Photogrammetry (mostly close range photogrammetry).

The applications of photogrammetry are widely spread. Principally, it is utilized for object interpretation (What is it? Type? Quality? Quantity) and object measurement (Where is it? Form? Size?).

Aerial photogrammetry is mainly used to produce topographical or thematical maps and digital terrain models. Among the users of close-range photogrammetry are architects and civil engineers (to supervise buildings, document their current state, deformations or damages), archaeologists, surgeons (plastic surgery) or police departments (documentation of traffic accidents and crime scenes), just to mention a few

Short description of photogrammetrical techniques:
Photographing Devices
Metric cameras
Stereometric camera
Amateur“ cameras

Photogrammetric Techniques

Depending on the available material (metric camera or not, stereopairs, shape of recorded object, control information...) and the required results (2D or 3D, accuracy...), different photogrammetric techniques can be applied. Depending on the number of photographs, three main-categories can be distinguished.

. Mapping from a single photograph

Only useful for plane (2D) objects. Obliquely photographed plane objects show perspective deformations which have to be rectified. For rectification exists a broad range of techniques. Some of them are very simple. However, there are some limitations. To get good results even with the simple techniques, the object should be plane (as for example a wall), and since only a single photograph is used, the mappings can only be done in 2D

The rectification can be neglected, only if the object is flat and the picture is made from a vertical position towards the object. In this case, the photograph will have a unique scale factor, which can be determined, if the length of at least one distance at the object is known.

Very shortly, we will describe now some common techniques:

Paper strip method

This is the cheapest method, since only a ruler, a piece of paper with a straight edge and a pencil are required. It was used during the last century. Four points must be identified in the picture and in a map.From one point, lines have to be drawn to the others (on the image and the map) and to the required object point (on the image). Then the paper strip is placed on the image and the intersections with the lines are marked. The strip is then placed on the map and adjusted such that the marks coincide again with the lines. After that, a line can be drawn on the map to the mark of the required object point. The whole process is repeated from another point, giving the object-point on the map as intersection of the two object-lines.

Optical rectification

Is done using photographic enlargeners. These should fulfill the so called „Scheimpflug condition“ and the „vanishing-point condition“. Again, at least four control points are required, not three on one line. The control points are plotted at a certain scale. The control point plot is rotated and displaced until two points match the corresponding object points from the projected image. After that, the table has to be tilted by two rotations, until the projected negative fits to all control points. Then an exposure is made and developed.

Numerical rectification

Again, the object has to be plane and four control points are required. At the numerical rectification, the image coordinates of the desired object-points are transformed into the desired coordinate system (which is again 2D). The result is the coordinates of the projected points. Differential rectification If the object is uneven, it has to be divided into smaller parts, which are plane. Each part can then be rectified with one of the techniques shown above. Of course, also even objects may be rectified piecewise, differentially. A prerequisite for differential rectification is the availability of a digital object model, i.e. a dense raster of points on the object with known distances from a reference plane; in aerial photogrammetry it is called a DTM (Digital Terrain Model).

Monoplotting

This technique is similar to the numerical rectification, except that the coordinates are here transformed into a 3D coordinate system. First, the orientation elements, that are the coordinates of the projection center and the three angles defining the view of the photograph, are calculated by spatial resection. Then, using the calibration data of the camera, any ray, that came from the archaeological feature through the lense onto the photograph can be reconstructed and intersected with the digital terrain model.

Digital rectification

The digital rectification is a rather new technique. It is somehow similar to „monoplotting“. But here, the scanned image is transformed pixel by pixel into the 3D real-world coordinate system. The result is an orthophoto, a rectified photograph, that has a unique scale.

Stereophotogrammetry

As the term already implies, stereopairs are the basic requirement, here. These can be produced using stereometric cameras. If only a single camera is available, two photographs can be made from different positions, trying to match the conditions of the „normal case“. Vertical aerial photographs come mostly close to the „normal case“. They are made using special metric cameras, that are built into an aeroplane looking straight downwards. While taking the photographs, the aeroplane flies over a certain area in a meandric way, so that the whole area is covered by overlapping photographs. The overlapping part of each stereopair can be viewed in 3D and consequently mapped in 3D using one of following techniques:

Analogue

The analogue method was mainly used until the 70ies of our century. Simply explained, the method tries to convert the recording procedure. Two projectors, which have the same geometric properties as the used camera (these can be set during the so called „inner orientation“), project the negatives of the stereopair. Their positions then have to be exactly rotated into the same relationship towards each other as at the moment of exposure (=„relative orientation“). After this step, the projected bundle of light rays from both photographs intersect with each other forming a (three dimensional optical) „model“. At last, the scale of this model has to be related to its true dimensions and the rotations and shifts in relation to the mapping (world) coordinate system are to be determined. Therefore, at least three control points, which are not on one straight line, are required (=„absolute orientation“).

The optical model is viewed by means of a stereoscope. The intersection of rays can then be measured point by point using a measuring mark. This consists of two marks, one on each photograph. When viewing the model, the two marks fuse into a 3D one, which can be moved and raised until the desired point of the 3D object is met. The movements of the mark are mechanically transmitted to a drawing device. In that way, maps are created.

Analytical

The first analytical plotters were introduced in 1957. From the 1970ies on, they became commonly available on the market. The idea is still the same as with analogue instruments. But here, a computer manages the relationship between image- and real-world coordinates. The restitution of the stereopair is done within three steps:

After restoration of the "inner orientation", where the computer may now also correct for the distortion of the film, both pictures are relatively oriented. After this step, the pictures will be looked at in 3D. Then, the absolute orientation is performed, where the 3D model is transferred to the real- world coordinate system. Therefore, at least three control points are required.

After the orientation, any detail can be measured out of the stereomodel in 3D. Like in the analogue instrument, the model and a corresponding measuring mark are seen in 3D. The movements of the mark are under your control. The main difference to the former analogue plotting process is that the plotter doesn´t plot any more directly onto the map but onto the monitors screen or into the database of the computer.

The analytical plotter uses the computer to calculate the real-world coordinates, which can be stored as an ASCII file or transferred on-line into CAD-programs. In that way, 3D drawings are created, which can be stored digitally, combined with other data and plotted later at any scale.

Digital

Digital techniques have become widely available during the last decade. Here, the images are not on film but digitally stored on tape or disc. Each picture element (pixel) has its known position and measured intensity value, only one for black/white, several such values for colour or multispectral images.

Pre-requisite: FWM 315