MONOPLOTTING IN A PC ENVIRONMENT

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ABSTRACT

Users of maps and photographs often wish to extract and combine information from both of these sources. At the Wageningen Agricultural University in the Netherlands a software package called MONOPLOT has been developed on a personal computer to achieve the above mentioned user's wishes.

In this paper an outline is given of Monoplot's concepts; into primary realisation, recent supplementary developments and planned additions.

INTRODUCTION

The desire to gather up to date information by means of images has grown considerably throughout the years. The cost of accumulating, computing, saving and manipulating data via an automated procedure, has become so low, the once reserved automation for the chosen few, has become common practice for many. Automation has not only influenced industry but also educational institutes to renew working methodes and reserach's fields of interest.

At the Wageningen Agricultural University in the Netherlands many faculties use maps and aerial photographs. Maps often form the topographical and geometrical base of a project area. Aerial photographs are used to extract additional information not available on the map. The interpreted information is transferred to the map by means of optical/mechanical instruments. The solution given to the user of aerial photographs, a non-photogrammetrist in this respect, are quite rigid and difficult to teach in a short period of time. It is evident that the wish to automate and streamline the procedure of interpreted information was great. At the same time, also the wish was made to try and fit this procedure into the expected developments of map production and information systems in the near future. As a result of the need described a computer program package called MONOPLOT was developed for a personal computer environment.

The intention of this paper, is to give a short summary of the developments made in the past, present and outline the future developments.

THE MAIN STRUCTURE OF THE MONOPLOT PROGRAM

Photo-interpreters gather different thematic information types from maps and aerial photographs. In each theme different terrain objects are classified, given a name and often presented for example by means of a specific drafting symbol. The geometry of the different objects depends upon its origin, in this case either a map or an aerial photograph. Often the map's or the photograph's geometry doesn't fit the map specification of the project. Then it is necessary to transfer the object to another geometry. Also when presenting the acquired information different map scales are needed due to the specifications given by the other map users.

To fit the situation described, a program called Monoplot has been developed consisting of four parts, these parts are the following:
- measuring the interpretation on a map and/or photo.
- transfering an object's point coordinates from one geometry to another.
- saving the interpreted/measured information in a file.
- presenting the information in a given geometry at a specific scale.

To accomplish the implementation of the MONOPLOT program, peripheral hardware is also needed. This need must not lead to the necessity to build or purchase specialized equipment. The standard equipment available in the automation world can supply the hardware components needed:
- a digitizer to measure.
- a personal computer to compute and operate the program.
- a floppy disk and/or a hard disk to save the data.
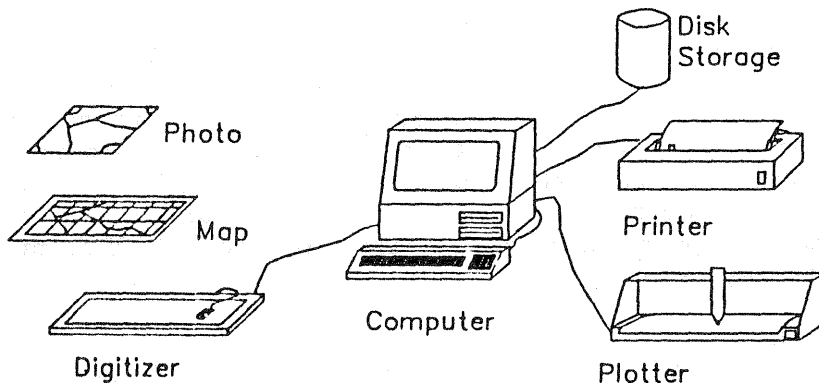- a plotter and a printer to present the information.

Fig. 1   Base components of monoplotting.

As can be seen in fig. 1 both a map and an aerial photograph use the same hardware components. Therefore the same working routine can be used; no extra instrumental education is necessary. The only difference lies between the projection of a map and that of a photograph.

BASIC MATHEMATICAL PRINCIPLES

The map
When using maps with large or medium scales, in general a plane similarity/affine transformation is used to transfer (x', y') coordinates of the measuring system to terrain coordinates (X, Y).

The plane similarity tranformation

$$\begin{bmatrix} X \\ Y \end{bmatrix} = \begin{bmatrix} a & -b \\ b & a \end{bmatrix} \begin{bmatrix} x' \\ y' \end{bmatrix} + \begin{bmatrix} cx \\ cy \end{bmatrix}$$

X, Y = terrain coordinates
x',y' = measured coordinates
a,b,c,d,cx,cy = the parameters.

The plane affine transformation

$$\begin{bmatrix} X \\ Y \end{bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} x' \\ y' \end{bmatrix} + \begin{bmatrix} cx \\ cy \end{bmatrix}$$

X, Y = terrain coordinates
x',y' = measured coordinates
a,b,c,d,cx,cy = the parameters.

Often on a map a grid is drawn, where map grid intersection points are known in terrain coordinates (X, Y). It is then possible to determine the parameters of the given equations. Respectively for a plane similarity/ affine transformation a minimum of 2/3 (reference/grid) points must be known in terrain coordinates and measured on the map to determine the 4/6 parameters of the equation. It must be of interest to the user to know the computed parameters are correct. Therefore the possibility to use more points to determine the parameters must exist. In the MONOPLOT program a maximum of 25 points may be used.

The aerial photograph

The mathematical relationships between a map and an aerial photograph are different. This is due to the projection types both images have:
- a map is an orthogonal projection.
- a photograph is a central projection.

A Map's Projection   A Camera's Projection
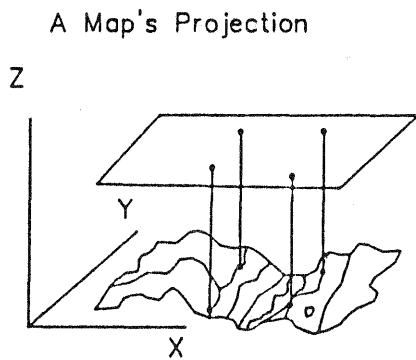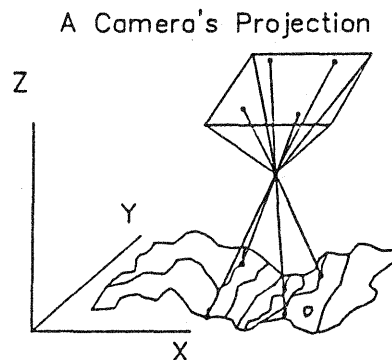
Fig. 2   Fig. 3

As shown in Fig. 2, the terrain points are projected perpendicular to the map's reference plane. This results in an image with a uniform scale. This is not the case with a photograph. It is assumed that sunlight is reflected from a terrain point in a straight line through the camera's lens and is then projected to the image plane of the camera (see Fig. 3). This assumption is sufficient for many applications of monoplotting.

The mathematial expressions used when monoplotting are well known in photogrammetry. The computation can be split up into two parts (the interior orientation and the exterior orientation see Fig. 4).
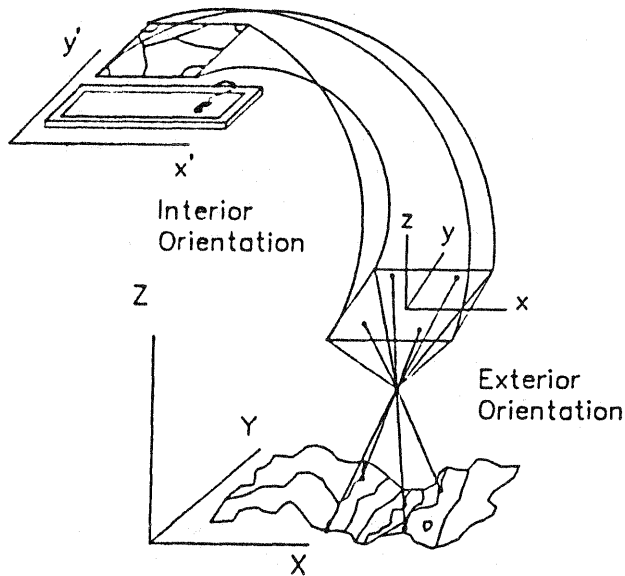

<u>Fig. 4</u>

The interior orientation allows for the transfer of a measured point (x' y'), received by the digitizer in this case, to the camera's image plane (x, y, 0). The exterior orientation allows for the transfer of camera points (x, y, 0) to terrain coordinates (X, Y, Z).
The mathematical expressions used are:
- a similarity or affine transformation for the interior orientation.
- a numerical restitution for the exterior orientation.
The similarity and affine transformation have already been given in the foregoing chapter.

The Numerical Restitution

$$
\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} X0 \\ Y0 \\ Z0 \end{bmatrix} - \mu p \cdot R3 \cdot \begin{bmatrix} xp - xo \\ yp - yo \\ c \end{bmatrix}
$$

X, Y, Z   = terrain coordinates
X0,Y0,Z0 = terrain coordinates of the camera's exposure center (see Fig. 4)
μp   = lengthfactor of the point p
R3   = the rotation matrix of the camera's angle of tilt defined in the terrain system
xp,yp   = the camera coordinates in the image plane of the measured point p
xo,yo   = the coordinates of the camera's origin

c   = the cameraconstant; the distance between the perspective lens's center the camera's origin in the camera's image plane.

In both parts of the computation, reference points are required to determine the values of the parameters. At least 2 fiducial marks (see Fig. 4), which are present on photographs made with a metric camera, are used as reference points for the interior orientation. The coordinates of the fiducial marks are known in the camera system. For the exterior orientation at least 3 ground control points (terrain reference points) must be known. These are points which can be seen on the photograph and known in terrain coordinates (X,Y,Z). The ground control points can be acquired from different sources for example a map or an aerial photograph plus the additonal height information, a photogrammetric block adjustment or by means of a terrestrial survey.

By measuring both the fiducial marks and the ground control points, it is possible to compute the parameters of both the interior and exterior orientation. In practice the use of more than the minimum number of reference points for both computations is advisible to receive a reliable estimation for the parameters.

Once the parameters are known, the problem of monoplotting is to find the terrain coordinates X, Y, Z for each measured point x', y'. The transfer of a measured coordinate to a camera coordinate presents no problem because there are 2 equations with 2 unknowns (x,y). But for the transfer of a camera point to its terrain point, there are 3 equations with 4 unknowns (X,Y,Z and μ). Therefore additional information is needed for monoplotting, this being the height Z of the points to be computed. As known in photogrammetry when using rectification or orthophoto techniques, the accuracy of the height needed is related as a percentage of the flying height. In practice usually a standard of 1-2% of the flying height is good enough for these techniques.
After this short description of the mathematical relationships used in monoplotting, an outline of the monoplotting system will be given as designed at the dept. of Landsurveying and Remote Sensing of Wageningen.

THE PAST DEVELOPMENTS

As stated in the beginning of this paper, photo-interpreters are interested in different terrain objects. Because of the numerous field's of expertise within the university interested in the monoplotting program, an open registration system of the terrain object's interpreted had to be found. It is nearly impossible to define all the object names used during a project. Each interpreter wishes to use his own object names before he starts with the program. The input of each object name is done by means of the keyboard of the computer.
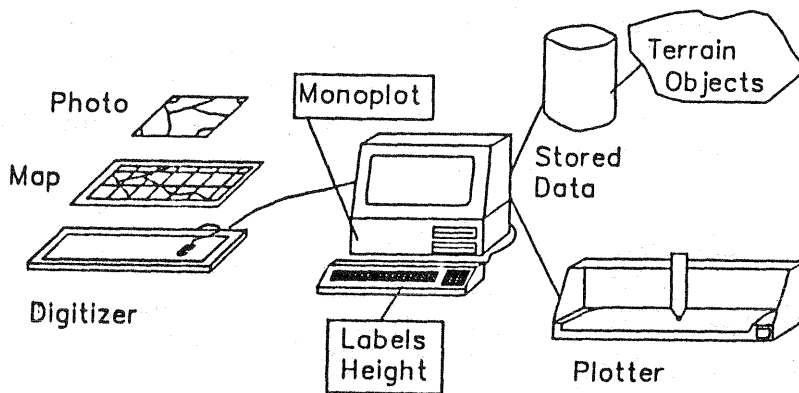
Fig. 5

Also a solution to registrate the terrain height during measurement had to be found. As described in the previous chapter, to use a single aerial photograph the approximate height of the object must be known. This can be known by means of a contour and/or spotheight map. The height information can be digitized and be superimposed over the photograph by means of a plotted transparent overlay. This will be discussed in more detail later in this paper.

Once this has been done, the height can be changed according to the height accuracy needed. This is not a very elegant method but in areas where the need to change the terrain height is sparse, this method can fit the purpose.

Besides the registration of information, users wish to present their information as well. When developing the monoplotting system, one of the extra possibilities for presentation is an overlay for either a map or an aerial photograph.

Photo interpreters often compare actual situations with planned situation. It is then of interest to combine interpreted information such as the terrain situation shown on the photograph along with the height information presented by contourlines and spotheights (see Fig. 6).
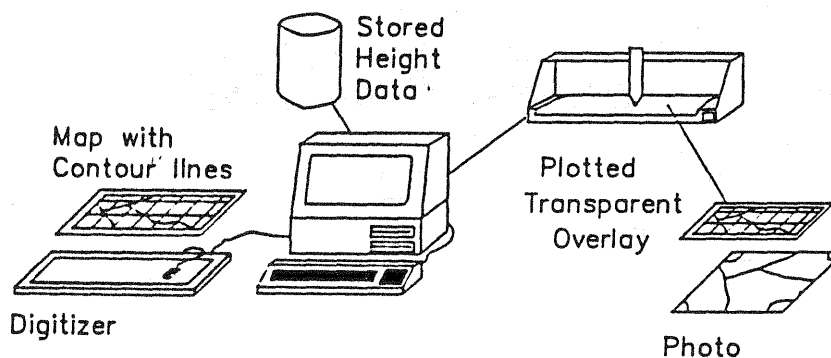

Fig. 6

If this is done for both aerial photographs used during interpretation, the information of file can be presented as a stereo image (see Fig. 7). If the height accuracy can be increased, the better the quality of the stereo image. This can be done by using a D.E.M. (Digital Elevation Model). This aspect will be discussed later.
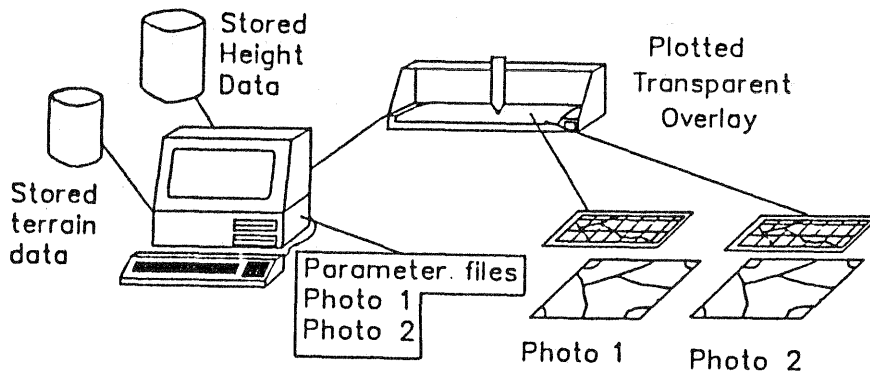

Fig. 7

As with the modern analytical stereo-plotters with superimpositioning, the advantages of such a facility for map revision and for the analysis of different information sources can be of great importance when making plans, inventories, or updating.

When measuring on a map or a photograph, mistakes are always made. In general two types of mistakes are made.
- geometrical (measuring)
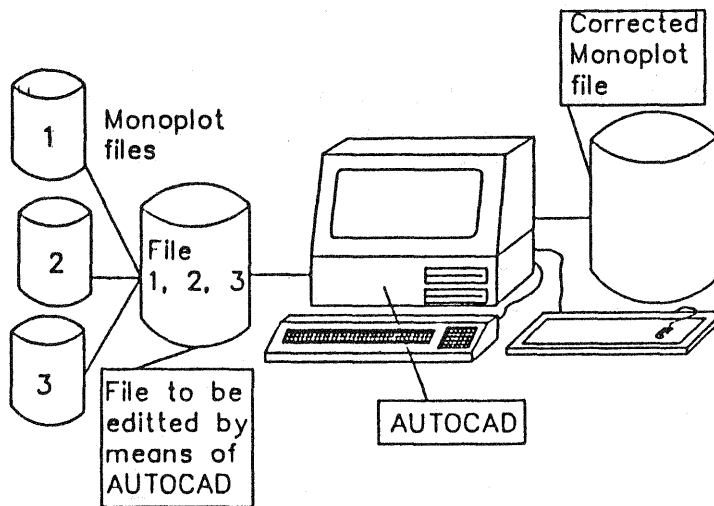- interpretation (defining the object's name).

Fig. 8

Measured lines or points may need to be (re-)moved or added. These editing aspects are well known in a number of computer aided design (CAD) programs

which have been made to work in a personal computer environment. Therefore the direct need to develop these facilities within the monoplotting program were not taken into consideration. Instead the monoplot files are translated to the input format of the program AUTOCAD. With this program, the necessary changes can be made. At the same time, the program offers a great number of cartographic features which can be used to prepare the final drawing in a project.

It must be stated to change an object's name once it has been defined and stored can be done within the program AUTOCAD. However it is very time consuming if this must be done often.

THE PRESENT DEVELOPMENT

One of the first requests made to alter a feature in the Monoplot program, was to automate the keyboard height input (see Fig. 5). To achieve this, a Digital Elevation Model must be made. When developing this supplementary program, a topographical map was considered to be the main source of the height information. Contourlines, profiles and any line defining the terrain's surface (fault lines) can be used to make the DEM. The fault lines can be given with or without height. The lines can be accumulated by the program Monoplot.

This option can be used to add the height coordinate to a terain position computed from a map as well as to better the computation of a terrain point when using a photograph. Also the data acquisition time is reduced especially when working in areas where the height differences are great. Extra programs have been made to compute contour lines, slope percentages and slope directions by means of the determined DEM.
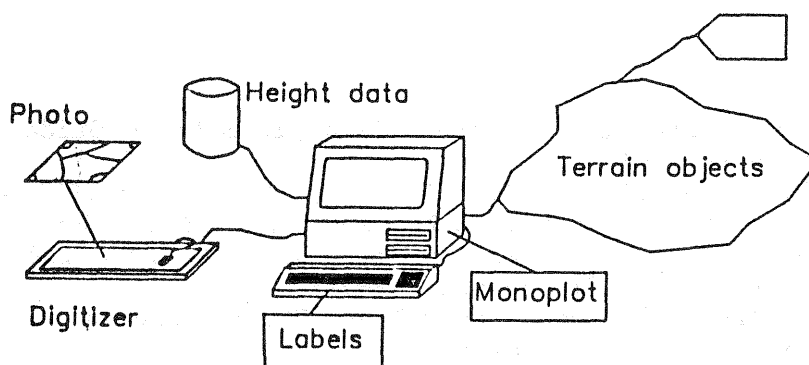

Fig. 9 Monoplot plus the support of a DEM.

THE FUTURE DEVELOPMENTS

It is not only the user's wish to gather and present information but also to use this later for example in the making of plans, inventories etc.

Database Management Systems (DMS) have proven to be of great assistance in this respect. The difficulty is however to structure the data so it fits into your system and the answers can be given to the questions you wish to ask. This often means the data must be rearranged according to its topological and/or thematical relationships. Based on the conceptual approach of a geographical information theory for polygon data described in the paper "Single Valued Polygon Maps" by Molenaar (3) preperations are being made to integrate these concepts with a DMS (in this case ORACLE, TURBO DATABASE). By means of this concept it is the wish to better the efficiency of editing and queries, not only in a geometrical sense but especially in a thematical sense.

Photo interpreters also use remote sensing images in their work. Image processing is used to help classify objects of interest. Often the boundaries of objects are difficult to determine. It is obvious that both the object information received through monoplotting and the object classification done by image processing should be integrated into one working procedure. Around the image processing program ERDAS, supplementary program developments are now taking place to realize the integration of image processing with a DMS as described above.

FINAL REMARKS

Monoplotting has proven to be a helpful tool in accumulating information for photo interpreters. It is meant to be a tool to gather bulk data easier and cheaper than in the past. Based on the mathematical relationships of a map or a photograph the objects positions can be determined with sufficient accuracy and it has helped to form further insight to develope working procedures to find a link with GIS.

REFERENCES

1. Alberts, J. and Kreiling, W., 1980. Photogrammeteric Guide (Karlsruhe: Herbert Wichman Verlag).
2. Makarovic, B., 1973. Digital Monoplotters, ITC Journal 1973-4.
3. Molenaar, M., 1988. Single Valued Polygon Maps, ISPRS, Commission IV.
4. Radwan, M.M., B. Makarovic, 1980. Digital Monoplotting System Improvements and Tests, ITC Journal 1980-3.
5. Slama, G.G., (Editor), 1980. Manual pf Photogrammetry (Falls Church, American Society of Photogrammetry).