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# The upbringing of Analytical Photogrammetry to meet the requirements of Cartography.

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## Abstract.

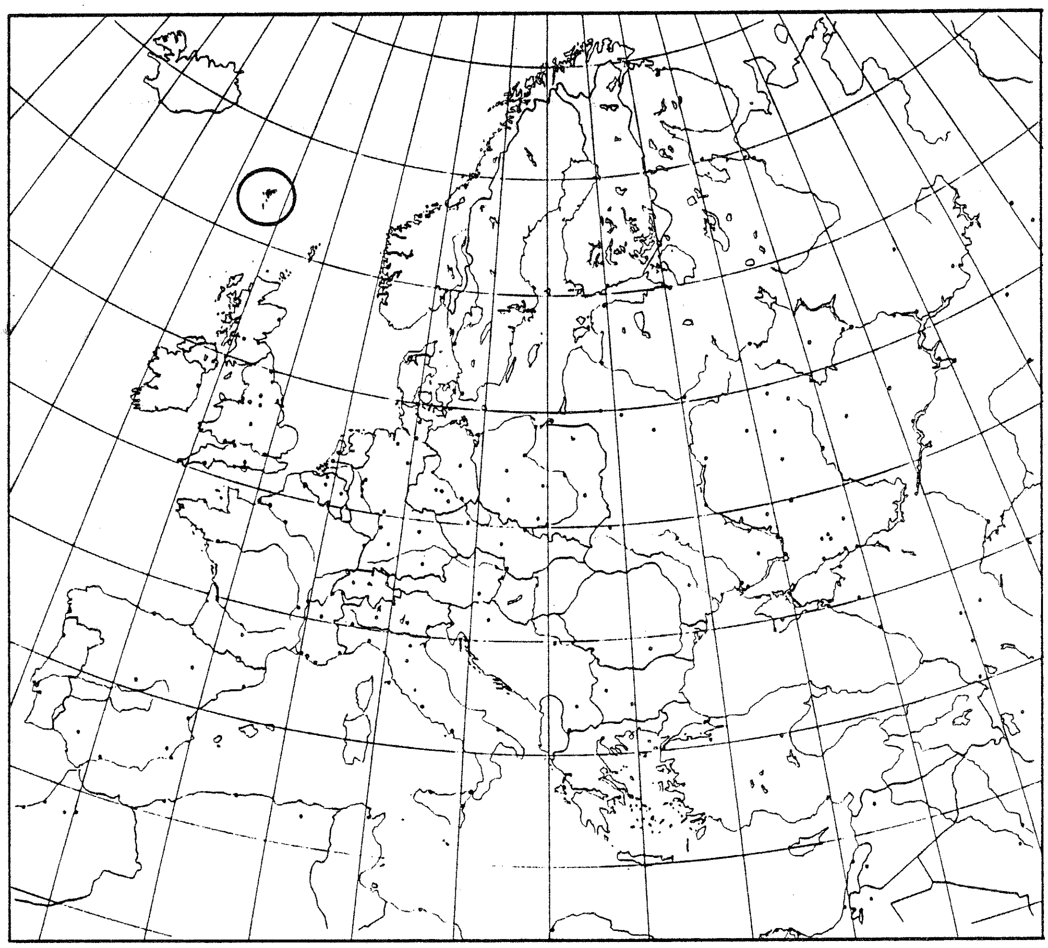
Analytical photogrammetry is by now established as a natural subset of a total photogrammetric setup. This paper deals with the use of standard analytical plotters for medium and small scale topographic mapping in general. Very high cartographic demands are put on topographic maps, regarding both design and contents. To the usual concept of accuracy, that is geometrical accuracy, are therefore added an element of what one might call "cartographic accuracy". This principle is used for a topographic mapping of the Faroe Islands at a scale of 1:20 000, using an analytical plotter for the map compilation.
Cartography must define the demands, and the analytical photogrammetry and its instruments must be further developed and brought up to meet the requirements.

## Introduction.

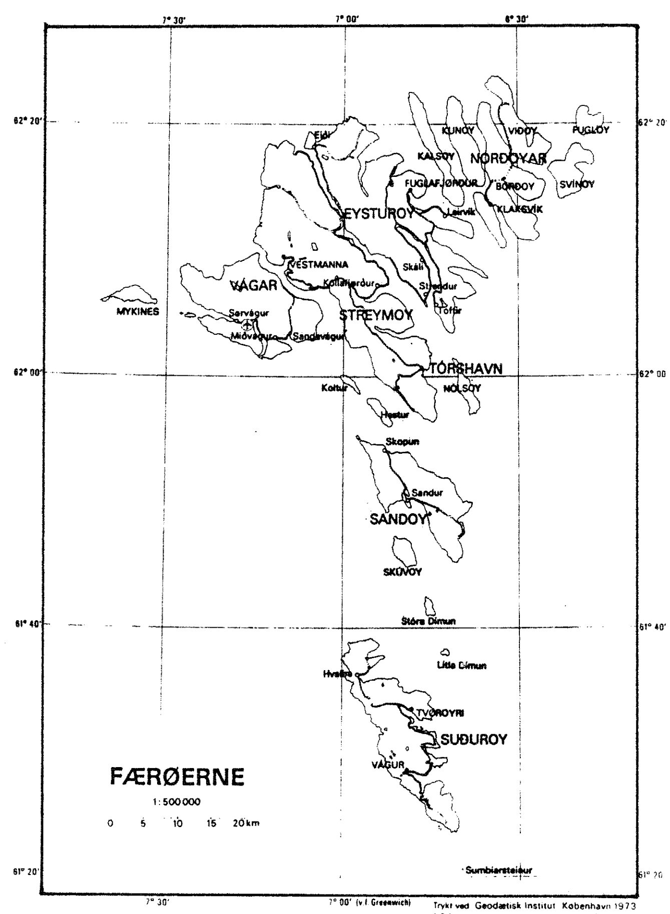
During the last decade there has been a clear trend in photogrammetry towards an increasing use of analytical methods and instruments. Due to the development of various digital equipment and instruments for photogrammetric use, and, above all, due to the constantly decreasing cost-benefit ratio of analytical plotters, analytical photogrammetry is by now established as a natural subset of a total photogrammetric setup.
In the field of traditional, topographic mapping, analytical instruments and methods has mainly (i.e. almost only) been used for aerotriangulation, and for systematic acquisition of heights (grid-data) for digital terrain modelling. In recent years, analytical methods are also being used for large scale cadastrial mapping of urban areas, more often within a setup which also includes some sort of interactive graphic computer system.
Although the establishment of digital terrain models usually results in the production of orthophotos and orthophotomaps ( [2] , [3] ), analytical methods are hardly ever used for proper topographic mapping. This paper deals with the use of standard analytical plotters for medium and small scale topographic mapping in general.
Very high cartographic demands are put on topographic maps, regarding both design and contants. Computer-like hybrid maps are therefore not acceptable, and cosmetic features, such as smoothing of contour lines, are topographical inaccurate, especially regarding base maps, as also pronounced bends are smoothed as well, and furthermore are these methods not yet suitable for other topographic objects. To the usual concept of accuracy, that is geometrical accuracy, are therefore added an element of what one might call "cartographic accuracy". The weight are to be attached to this notion, rather than to the usual geometrical accuracy, and accuracy in object description in every respect, becomes the very ideal.

## Mapping of The Faroe Islands.

The principles just outlined are used for topographic mapping of the Faroe Islands at a scale of 1:20 000. An analytical plotter is used for the entire map compilation. All topographic details are carefully measured, described and stored in a simple sort of a topographic data base. The stored data are to be utilized to the largest possible extent, in various appropriate places in the production.



The previous base map 1:20 000 of the Faroe Islands was originally compiled during the years 1895 - 1899. Field reconnaissance was carried out in 1938 and 1971, and the maps completely revised. Not until doppler-measurements was carried out in the years of 1968 and 1976, the accurate geographic position of the Islands was finally determined. Considering these circumstances it seems reasonable to produce a quite new base map of the Faroe Islands, achieving the geometrical accuracy to equalize the brilliant cartographic quality of the previous maps. The new maps are also produced at a scale of 1:20 000, but naturally by means of photogrammetric methodes solely. By agreement with the Faroese, the photography is taken at an image scale of 1:15 000, by which the quality of the measurements will be sufficient, both geometrically and cartographically (i.e. regarding contents), for the additional purpose of forming the basis of further cadatrial mapping at the scale of 1:5 000.




The Faroe Islands is situated in the middle of the wind-swept Northatlantic Ocean. It consists of app. 20 individual islands, all volcanic in origin. Water- and winderosion has formed this magnificent beautiful landscape, which is completely unfit for any mapping procedure, and the weather conditions makes flying difficult and photography almost impossible. The flight missions started in 1982 and we have not yet succeeded in getting a complete coverage, although the total area is only about 540 sq. miles (1400 $km^2$). The photography is carried out from two different flying heights, at image scales of 1:30 000 for the purpose of aerotriangulation, and 1:15 000 for the map compilation. In order to facilitate the interpretation, and thereby increase the cartographic accuracy, are color aerial film used for the 1:15 000 photographs.

Originally this project was planned back in 1982 as an ordinary mapping project, using traditional photogrammetric methodes. But unexpected grants made it possible for The Geodetic Institute to purchase an analytical plotter, Zeiss Planicomp C 100, and we decided to use this instrument for the new mapping project. We take hereby the opportunity of risking the attempt to make a complete and pure digital topographic mapping instead of a traditional, graphic mapping. The limited dimensions of the area and the natural dividing effect of the islands makes it very suitable as a pilot project for digital topographic mapping. As most topographic details and objects, exept for wood, are represented, the project also becomes illustrative for further general utilization.

The cartographic demands put on the final maps are of equal high level as the ones usually put on our ordinary, hand-engraved maps. Of course this can easily be achieved simply by handengraving the new maps, but as all the detailes are being digitized it will be advantageous to utilize the data for automatic engraving. But the demands for quality are unchanged and we are not going to compromise to, on the computers terms, accept any computer-like maps. Nor all objects are suited for direct automatic engraving. Some sort of cartographic treatment, such as selection, elucidation, simplification and correct cartographic dimension, placement and displacement, is indispensable. Those types of objects who does not need any further cartographic treatment goes directly to automatic engraving. In order to meet the requirements of graphic quality, we have to make sure that the stored data does have sufficient reliability and density for the objects to be described accurate enough to obtain a perfect engraving.

The measurements include both heights and the usual topographic objects, that is houses, roads, ports, fences, dikes, lakes, rivers, high-voltage lines and pylons, e.t.c.
The measuring procedure is quite simple. The operator must have the opportunity to arrange his own working plan, and must be allowed to measure the different objects in an arbitrary sequence, and possible difficulties must be solved by the software. During the entire measurement a plotting table is permanently connected to the instrument, monitoring the progress in the measurements. Each and every object is of course equipped with a simple internal digital code, and they can be measured in an arbitrary order, and from different photogrammetric models. Curved, line-type objects, such as coast lines, lakes, rivers, roads, e.t.c., are measured as polygons, having sufficient point density for the following direct automatic engraving. For this purpose we collect coordinates each 0.3 sec. (~ 2 - 5 m.). The time-release mode causes optimum description of the expiration of the line. The rest of the objects (houses, fences, pylons, e.t.c.) are represented by characteristic single points, i.e. corners, bends and nodes.

Heights can be measured and represented in various manners. The geologi of this area, hills traversed by ravines, sills and dykes and terminated by precipitous cliffs, are not tempting for grid-like type of height measuring. In that case progressive sampling in a very dynamic grid must be used, and this procedure causes severe difficulties in the connection of several models. We prefer to measure the contour lines directly, just like a traditional analog instrument, and collect coordinates in the same way as for other line-type objects. This procedure is some more time consuming, but in return it gives us some advantages. To begin with is the procedure well known to the operator and, unlike grid-measuring, certainly not tedious. During the contouring the operator visits all parts of the terrain and pictures hereby the whole area, which benefits him during the following search for all the remaining topographic details. The representation of the contour lines becomes optimum, and well suited for automatic engraving, with an absolute satisfactory quality. The point density is stipulated high enough (the measuring time for contouring is independent of the point density) for the data also to be utilized even at a somewhat larger scale. The traversed landscape causes some blind areas in the pictures, and thereby holes in the model. The measuring procedure allows complementary measurements from adjacent models, in order to fill out such blind areas. The large amount of data, and the thorough description of the surface (contour lines at vertical intervals of 10 m., and 5 m. within inhabited areas) justifies and facilitates interpolation into an arbitrary grid, for example for production of orthophotos.

All the measured data are stored on disc files in ground units, UTM-coordinates. The data storage and filing system makes the data retrieval independent from model- or sheet-boundaries. Data or subsets hereof can be selected within arbitrary defined areas.

When the summer comes, goes the topographer into the field, in order to verify the photogrammetric plots by complement them with possible missing detailes, or to correct misinterpretated objects. Any possible alterrations since the pictures was taken, are carefully inserted. In order to supply the topographer with the best suitable material, he carries not only the plots, but also orthophotos covering the whole area, and at the same scale. Some important objects are to small for reliable recognition at the pictures (e.g. cairns, pylons, e.t.c.) and the topographer performs a simple intersection in the field.
So the topographer returns with very detailed corrections to the photogrammetric plots, and thereby also to the already stored data. The first revision takes place before the map is published, or even printed. To my shame I must admit that we don't have any sophisticated sotfware for performing this task,

not yet, but we are working on it. For the time being, we simply look up the erroneous data, delete or correct them, and supplement with new measurements or calculated coordinates. The method is rather slow, inelegant, but absolutely reliable.

We do not produce "a digital map". We are producing a topographic map, using digital methods to the largest possible extent. By doing this, we are establishing a complete digital topographic database.

## Cartographic accuracy.

The notion "cartographic accuracy" is valid for both the data acquisition phase, as well as for the phase of data representation. The main emphasis lays of course on the representation of data, and thereby on the final product.
A condition for a fair representation is that necessary considerations are taken, already during the phase of data acquisition.
Topographic objects does always have a certain physical extension. Some objects are of rather irregular shape, or have a somewhat diversified lapse. Such objects are not easily to describe by selected single points. Regardless of the obtained geometric accuracy of the coordinates, is it often more decisive to know what is going on between the points. A reasonable cartographic accuracy is only obtainable by increasing the point density, until the string of points describes the whole object sufficient accurate, of course within a certain range of scale ratios. Scales, that is both image scale as well as publication scale, are also decisive for the obtainable amount of details. The cartographic significance of an object, is not necessarily directly proportional to its physical extension, and all details forming parts of an object are not necessarily of equal importance. Some details are more dispensable than

others, and specific characteristic details are certainly not to be lost. Another cartographic aspect is the elucidation in the representation of the objects at the final map. Geometrical correct placement of all objects causes that different kinds of objects in some cases are to be drawn on top of each other, due to their actual closeness, and the chosen scale ratio. In these cases are the cartographic accuracy predominant to the geomatrical, and some objects, or parts of objects, are to be depicted at geometrical incorrect places. We do not want to profane our database with such geometric garbling, but are handing it over to the subsequent cartographic treatment, to take this considerations into account. Neither we have found or developed any methods to handle these problems automatically.

## The part of the analytical plotter.

What have all this to do with analytical plotters, you might ask. The plotter is of course unsurpassed for the aerotriangulation phase, but photogrammetric data acquisition can be performed at any photogrammetric instrument, having the necessary digitizing equipment, and sufficient data storage capacity. But quite a few aspects convince me, that the analytical plotter is <u>the</u> instrument for this task. I am not only thinking of a future generation of analytical plotters, especially constructed for topographic measurements, but also of the plotters well known today, as they already do have several of the features, necessary to solve the task in a practicable way. Working in a rough terrain, as the Faroese, is it necessary to pick up information from several adjacent models, in order to complete the one model you are actually measuring. Frequently shift of models are therefore inevitable, and only practicable due to the analytical plotters very simple and fast orientation procedures, and the facilities of storing the orientation parameters. Not at least the many precipitous coast-models, which have a very unfavourable land/water contribution, benefits hereof. The possibility of moving the instrument to specified points are frequently utilized, especially to secure the graphic continuity between the models. This facility is also decisive for the subsequent revision, as it makes it possible to fast and reliable move the instrument to that specific location, where the correction or complementation are to be made. Unfortunately are the analytical plotters not yet especially designed for topographic work, and one could wish a few more facilities for this purpose.

## A caricature of the analytical plotter.

Considering the analytical plotters known today, is it obvious that they are nothing else but some very sophisticated developed stereocomparators. The troublesome, and regarding actual model measurement destructive, and unceasing correction of parallaxes, has been automated. The computer, necessary to perform and controle these corrections of the picture carriers, is further utilized to take over the basic photogrammetric procedures, mainly the procedures of orientation. Furthermore the computer is used to move the instrument to specified single points, or to guide the instrument at a predetermined pattern (profile, scanning, cross-sections). The former purpose is clearly a heritage from the comparator-age, mented for the task of aerotriangulation, the main application of the comparator, and for which the analytical plotter is constructed. The second purpose has come to later on, and expresses an increasing need for systematic collection of heights, to describe the topographic surface (digital terrain models, orthophotos). In both cases, the task is all about measuring of single points, and the very philosophy seems to be rather traditional. For topographic use are the line-orientated philosophy of the analog instrument missing, which could be a very powerfull combination with the computers suitability of processing, storing, searching and sorting huge amounts of data.

## Science fiction.

The point-operational features are of course indispensable. But if the analytical plotter is going to have a topographic future, is it absolutely necessary to further improve the facilities with some line-orientated and object-orientated features. The datastructure must be changed radically, in such a way that the possibilities of searching, correcting, updating, e.t.c., within the data (including previous measurements) are substantially improved.
One way to design a topographic datastructure, is to devide the lines into segments, connected by nodes. The nodes can be bendpoints or points of ramification, or just serving the purpose of splitting long lines. The nodes are stored with absolute coordinates, and between the nodes relative coordinates will be sufficient. By the nodes the line segments are completely described, with regard to kind, coordinates, storing and all other characteristic informations. Thereby the nodes makes out the very key for an effective searching and sorting for possible corrections. Whole objects can be treated in a similar manner, at least if they are of moderate dimensions. As an example, a house can be described by just one pair of absolute coordinates for the central point, and relative coordinates for the corners. The strategy can also be used for other small areas, limited by polygons. Besides an essential simplification of the handling and storing of data, results this structure also in a powerfull improvement in the conditions of revision. Then it would be possible to guide the instrument, not only to single points, but directly to specified objects, or following selected line segments.
Of course all this is software problems, and the individual user can develope his own programmes accordingly to the actual task. But should this be a problem to each and every user, or isn't it reasonable to expect these features to be obvious parts of a complete analytical system, on a par with the point-orientated modes of operation. Even a rather primitive database system considers some of the mentioned

shortcommings, but it must be structured in a quite different way than most of the common administrative database systems available.
The line-orientated developement can also affect the hardware of the instrument. Image correlators, devices for primitive pattern recognition and color analysis can possible be used for semi-automatic measurement of the limitations of moderate size areas, or perhaps be able to follow evident line paths. A more pure digital treatment of pictures, objects, informations, e.t.c., instead of just coordinate manipulations, are to be expected. My imagination is limited, I must admit, as all these proposals consists of already well known elements. Hopefully reality will exceed my fantasies. But one point is perfectly clear to me. It is imperative that the analytical photogrammetry realizies and are capable of developing itself towards a more line- and object-orientated philosophy. That is the demand put on analytical photogrammetry, if it is going to have any topographic future, without profaning the final cartographic product, by ceaseless entering into "computer compromises".

## The end.

Cartography must define the demands, and the analytical photogrammetry and its instruments must therefore be further developed and brought up to meet the requirements. Only then becomes the analytical photogrammetry, not only an useful but also an indispensable element in the production of topographic maps.

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