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PRODUCTION AND USE OF ORTHO PHOTO MAPS IN SWEDEN

by LARS OTTOSON

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Abstract

Photo map production has a long tradition in Sweden. Thus the production of the General Land Use Map at the scale of 1:10 000, which is the basic official map of the country, has been based on photo maps since the map series was started in the middle 1930's. Since 1966 these basic photo maps have been produced using ortho photo technique.

Initially the Gigas-Zeiss system was used but now an Avioplan equipment is utilized. The paper gives details regarding different methods used in elevation data acquisition as well as concerning the establishment of a high density terrain elevation data base covering the whole country.

The paper gives examples of the use of ortho photos in forestry, physical planning and in production of street index maps. Moreover production of colour and stereo ortho photos as well as problems in reproduction of ortho photo maps are treated.

The total area now covered with ortho photo maps is about 320 000 sq kms (70 % of Sweden).

Ortho photo maps already play an important role in Sweden but they are expected to be of even greater significance in the future.

PRODUCTION AND USE OF ORTHO PHOTO MAPS IN SWEDEN

Introduction

Photo maps have played an important role in Swedish map production since the middle 1930's when the publishing of the General Land Use Map (Economic Map) at the scale of 1:10 000 or 1:20 000 started.

The Economic Map (1) is based on a photo map background and also contains planimetric details such as buildings, roads, railways, power lines and hydrographic features. The map also shows the subdivision of the country into counties, judicial districts and communes. Parishes are also shown for land registration purposes and within this framework the division into separate properties is shown. Elevations are indicated by contours with a 5 metres interval. Lettering consists of names, information and various figures concerning properties etc. Arable areas are shown in yellow colour.

The photo map background has made it possible to carry out field work with very simple tools. The different planimetric details, which are to be shown on the map, are first drawn in pencil on the photo map in the field and thereafter, fine-drawn in ink after each day's field work.

Ortho photo technique

At the time when the production of the Economic Map started in the middle 1930's the photo map was produced as so called controlled mosaics. This method was used until 1966 when the first Gigas-Zeiss ortho photo projector was introduced into the production. Since then the production of the Economic Map has been based on ortho photo maps (2), (3).

Some years ago computer controlled ortho projectors appeared on the market. Realizing the great advantages offered by such systems the Land Survey started experiments and software development in 1976 in order to study the possibilities of introducing computer controlled ortho photo production. These experiments indicated great advantages particularly regarding image quality, flexibility and economy, and resulted in the acquisition of an Avioplan OR1 ortho projector system manufactured by the Wild Co, Switzerland. This equipment was introduced into regular production in 1978.

Using the Avioplan equipment it is necessary to have access to digital terrain elevation data with a high density. It is, of course, possible to acquire control information for each photo to be projected but in order to take full advantage of the great flexibility inherent in the computer controlled projection system it is rational to establish a high density terrain elevation data base to store adequate information in a suitable form.

Since ortho photo production is of very great importance in Swedish cartographic activities and is expected to be of even greater significance in the future, especially for map revision, the implementation of computer aided methods in ortho photo production has led to the establishment of a terrain elevation data base (4). This decision has, of course, also been influenced by the fact that the data base certainly is of great interest for many applications other than cartographic.

Acquisition of digital elevation data

There are three main possibilities for the capturing of basic information for the data base:

- Photogrammetric measurements of aerial photos
- Digitisation of existing contours
- Digitisation of existing profile plates.

Photogrammetric data acquisition can be performed in the profiling or contouring mode. Traditionally profile measurements have been widely used in ortho photo production to capture elevation data from aerial photos. One great advantage with this method is the fact that the time needed for the data capture is relatively independent of the terrain elevations, which is not the case if data is acquired in the contouring mode. For this reason, profile measurements will be used to a very large extent in data acquisition from aerial photos.

The terrain in Sweden is, normally, thickly forested which is one reason for not using automatic profiling devices which - at large expenses - are available on modern photogrammetric instruments. Instead, the Land Survey makes use of six Zeiss Jena Stereometrographs for profile measurements. These instruments have been equipped with digitising equipment for output on magnetic cassette tapes.

Over much of Sweden, high quality elevation contours have already been produced and this material can be used as a base for data acquisition. For the time being there are no automatic devices, such as raster scanners or automatic line followers, available in Sweden which can be used to digitise existing contours. Thus a present, the use of ordinary digitising equipment such as Bendix and Altek tables for data capture from elevation contours seems to be the most realistic solution.

There is no need to measure all details of the contours. Therefore, only intersection points between contours and a reference line raster are digitised. The line interval is normally 5 mm on the map, which equals to 50 m on the ground. Since this kind of data acquisition is relatively expensive, the method is used only in comparatively flat areas. Thus in areas with more hilly terrain it is at present more economic to use other techniques for gathering the data.

As regards the third main method for data capture, digitisation of existing profile plates, it has already been mentioned that ortho photos have been produced for large parts of the country. Since Gigas-Zeiss projectors have been used in this production in the so called off-line mode, glass profile plates have been used to store terrain elevation data in an analogous form. Thus a great number (ca 14 000) of these plates are available. Aerial photos taken from a flying altitude of 4 600 m have normally been used in capturing the information stored on the profile plates. Then the distance between adjacent profiles is 60 meters. It is possible to use the profile plates in elevation data acquisition. For this purpose one of the Gigas-Zeiss projectors has been equipped with shaft encoders and devices for output of digital coordinate data on magnetic cassette tape. This method works very well and of special interest is the fact that a profile plate can be recorded in less than half an hour. Using this method it is necessary to carry out additional measurements of a limited number of control

points of corresponding aerial photos. This is necessary in order to transform profile data to the national grid. Our experience is that digitising of existing profile plates is, in most cases, the fastest and most economic method for acquisition of digital elevation data. Thus, the fact that existing profile plates cover about 60 % of the country is of great economic importance in the establishment of the new terrain elevation data base.

The choice between the three main data acquisition methods is dependent on existing materials and their quality as well as on the conditions of the terrain and other natural features conditions. A total of about 400 000 sq kms are planned to be covered by the data base which corresponds to about 90 % of the country. Only the mountainous areas of the northern part of the country will not be included. The most frequently used technique will be digitisation of existing profile plates. This method will be used for about 220 000 sq kms. Digitisation of existing contours will be carried out for some 100 000 sq kms while the remaining 80 000 sq kms will be captured by photogrammetric measurements (mainly profiling) of aerial photos.

The time needed for data capture is significantly dependent on the method used and also to some extent on the configuration of the terrain. Normally, as already mentioned, the most rapid method is to digitise existing profile plates. In this case only about 3 hours per map sheet is needed. If data is acquired by profile measurements in photogrammetric instruments the time required will increase to about 16 hours. Existing contours are used as a base material only in relatively flat areas as well as in parts of the coastal archipelago. This method is used primarily in areas not covered by earlier profile measurements. However, in some very flat areas contours will be used even though profile plates are available. As an average six hours per sheet is the estimated time for this data collection method.

Thus, a total of about 50 000 hours will be needed to capture digital terrain information for the entire data base. The creation of the data base started in 1978. At present digital data has been captured for about one thousand map sheets. The data acquisition is carried out in accordance with a plan which takes into account the needs for digital information for production of ortho photo maps as well as for other activities. Due to the close connection between the production of ortho photos and the data base it is estimated that data acquisition will not be completed until country-wide coverage of ortho photo maps has been attained. This will approximately take another ten years.

Data processing and storage

Once basic elevation data has been acquired the information has to be fed into a computer system for processing and storage. At the present time all instruments used for data acquisition are off-line to the computer. Magnetic cassette tapes are used as communication medium.

The computer used is a Prime 400 system which is installed at the Land Survey office. This system now incorporates a core of 1024 Kbytes and a disc storage capacity of 700 M bytes.

An important stage of the data processing is an automatic error search to clean digitised data from systematic and gross errors. Experiments have shown that the majority of the gross errors introduced in the digitisation or in the transmission to the computer can be retrieved by effective

computer programmes and are easily corrected via an alpha graphic terminal without any remeasurements.

Many alternatives exist for storage of elevation data. The Land Survey, has, for several reasons, chosen to store elevation data in the form of spot elevations in regular grids. The sheet division adopted in the production of the Economic Map at scales of 1:10 000 or 1:20 000 is used as a base for the data base. Thus the grid size is 5 x 5 kms or 10 x 10 kms respectively. The grid interval is 50 or 100 m respectively. The grid interval of 50 m is used in southern Sweden as well as in many areas in the northern parts of the country. One important reason for choosing regular grids as storage units is that the future use of the data base is expected to be very much facilitated if regular grids are used. Thus in ortho photo production the computer time needed to generate control information for the ortho projection is minimized if the basic terrain information is available as regular grids. In many other applications, regular grids also serve as a feasable basis for computer processing. This is due to the fact that software already exists or can easily be developed for different applications by presumtive users of the data base. Another reason for choosing regular grids is that only z-coordinates need to be stored which is an advantage compared to other alternatives which normally call for additional storage of x- and y-coordinates.

Since data capture just in very few cases is performed for grid intersection points, it is necessary to transform measured values into grid points. A large number of methods are available for interpolation of grid intersections from measured points (5). At the Land Survey two interpolation methods developed by Akima (6,7) are utilized. They are based upon the use of so called bivariate functions. Numerous experiments have shown that Akimas methods give good results and require comparatively short computer times.

Each grid of the data base contains 101 x 101 or 10201 points. The final number of grids to be stored in the national data base has been estimated to 13 000 corresponding to about 130 milj points.

The fact that the information stored in the data base consists of interpolated values for grid intersection points naturally means that the geometrical quality is slightly poorer than that of directly measured points. However, experiments have shown that the interpolation technique which is used gives very good results for the kind of terrain that is common in Sweden. Thus, when digitising profile plates used to store information acquired from aerial photos at the scale of 1:30 000 the standard error of grid intersection points is of the order of $\pm$ 2.5 meters.

Experiences have shown that a close check of each grid is of great importance. Several methods can be utilized for this purpose. One method is to interpolate contours in the grid and plot them on a computer controlled plotter. Then these contours are compared to existing contours plotted in photogrammetric instruments. However, this method is relatively expensive. Therefore in the first place a computer based comparison between interpolated and known elevation values is used. Two sets of known elevation points can be used in this operation. On one hand photogrammetrically determined control points are compared to points interpolated in the grid. On the other hand an existing high quality elevation data base with a grid interval of 500 meters is utilized. Then 121 points are checked in each grid.

Abnormal differences are fed out on a line printer and are subjected to a closer examination.

As already stated the prime reason for the establishment of the terrain elevation data base is the production of ortho photo maps. However, digital elevation data is of great interest in many other applications. The following applications can be mentioned:

. Computing of cross sections i.a. for visibility studies
. Correction of remote sensing data
. Correction of gravimetric measurements
. Terrain corrections in flight simulator systems
. Different cartographic applications such as automated hill shading
. Military applications such as computer controlled navigation in aircraft and guided missiles.

The elevation data base will certainly rationalize the production of official maps especially by making the ortho photo process more flexible. Apart from this, the examples given above indicate that the database will be of great value in a variety of other computer based activities as well.

Production

Ortho photos have now been produced for 15 years in Sweden. This means that very large parts of the country have been covered with this map type, and the area mapped since 1966, when the first equipment was set up, is about 320 000 square kilometres. This corresponds to some 70 % of the total area of Sweden. The geographical distribution of the different areas is shown in Fig 1.

The first edition of the Economic Map has now been completed for the area to be covered by this map series. Thus the further production of ortho photos will serve as a base for the revision of this map. A desirable goal is to produce ortho photos for this purpose with a time interval for the whole country of about ten years.

Use of ortho photo maps

As already mentioned, the main reason for the Land Survey to produce ortho photo maps is to supply a suitable base for the Economic Map. Another very important reason for making ortho photo maps is to meet the need for good base map material for forestry mapping.

An inventory of lumber reserves in the areas managed by the State and the large private forest companies as well as the main part of the woods owned by private owners is carried out at intervals of 10-15 years. This inventory is normally coupled to a planning of future utilization and conservation measures. To support this work a special map is normally produced to give details concerning division into stands etc. This means that every year 15-20 000 sq kms need to be mapped on special forestry maps.

These forestry maps must include a survey of the ownership pattern, be usable for orientation in the field and be suitable for the presentation of planning as well as for registration of a variety of other activities. Photo maps can meet these requirements and are very suitable as a base for the production of forestry maps.

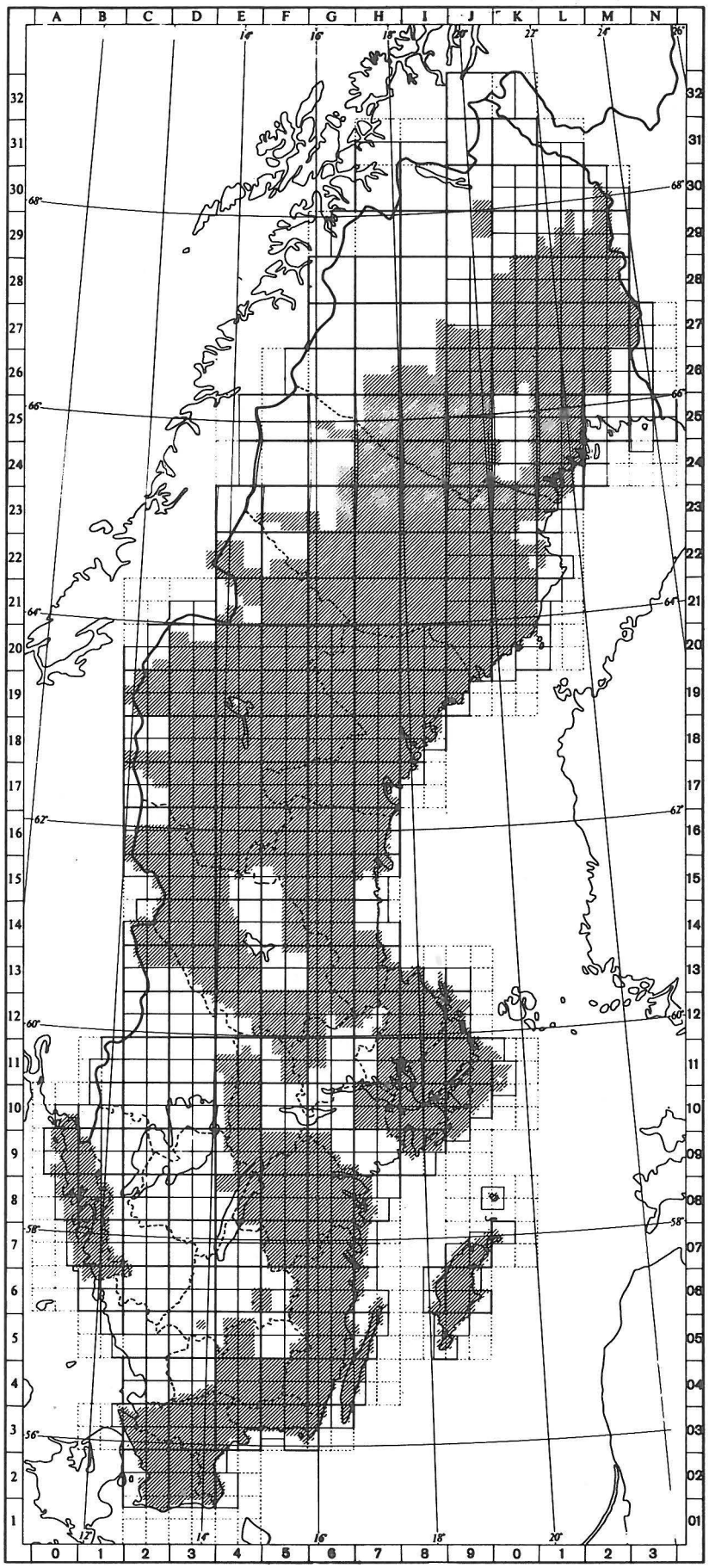

Figure 1.

Screened areas on the map of Sweden are covered with ortho photo maps at the scales of 1:10 000 or 1:20 000. As a total the maps cover about 320 000 sq kms.

Up to the 1970s manually produced controlled photo mosaics were the most widely used base in forestry mapping. To a limited extent this type of map is still used, but it is successively being replaced by ortho photo maps. This is due to the fact that during the last ten years demands for the geometric accuracy have increased due to the fact that a need for accurate area measurements on the base maps has become of increasing importance. But it is also due to the fact that higher geometric quality makes it possible to revise forestry maps without a complete redrawing of all old, unchanged, planimetric details in order to match these details with the new base map.

At the present time, ortho photo maps are the most commonly used base for forestry maps. In some cases it is possible to use ortho photo maps which have been produced as a base for the Economic Map. In remaining areas, ortho photo maps are produced by the Land Survey on a repayment basis. To quite a large extent these maps have been produced from aerial photos taken from an altitude of 9 200 meters.

The final forestry map is produced by copying the separate originals on plastic coated photo paper as well as on transparent film. The transparancy is made to be used as original in the production of diazo copies. These copies are used as working and planning maps in connection with felling, transportation etc.

So far the main application of ortho photo maps in Sweden has been concentrated to the scale range of 1:10 000-1:20 000. However, during the last few years an increasing interest for the utilization of ortho photos for different applications for maps also at scales of 1:2 000-1:5 000 has become apparent. This interest is very much dependent upon the possibility of using ortho photos as a base material for presentation of various plans for the general public or to the decision makers. For this reason a separate study is now carried out in order to find suitable ways of producing material in black and white or true colour for such purposes.

Yet another application is the production of street index maps. In some cases such maps have been produced using black and white ortho photos as a base material. In these cases, the ortho photos have been printed on the final map in a grey or green colour. Recently a street index map using true colour ortho photos has been published. In this case only lettering (street names etc) in black is used to give additional information.

Stereo ortho photos

Computer controlled ortho photo production also makes it possible to produce stereo ortho photos. In some countries, especially Canada, this technique has already been introduced. In other countries, however, the use of stereo ortho photos has not been found to have any impact on cartographic procedures.

At present it is not obvious that stereo ortho photos will become a useful tool in Swedish map production. However, it is possible that revision of the official maps at the scales of 1:10 000 and 1:50 000 could be supported by the utilization of stereo ortho photos. Furthermore a possible application of stereo ortho photos in forestry mapping can be envisaged.

In order to investigate the possible utilization or stereo ortho photos in Sweden the Land Survey has now developed adequate software for production of such maps and has also produced a limited number of stereo mates. These experimental sheets are now used in experiments to throw more light on the usefulness of stereo ortho photos in different cartographic applications.

Reproduction

In order to facilitate and stimulate the utilization of ortho photo maps inexpensive and simple methods for reproduction of such maps must be presented. Thus a study of different reproduction methods has been carried out at the Land Survey.

It is obvious that the best quality is gained in contact prints on photographic material such as RC-coated paper. However, this product is relatively expensive. This as well as the fact that silver based photographic materials are subjected to a rapid increase of costs calls for alternative methods. Furthermore the users ask for simpler ways of reproducing ortho photos in limited numbers.

Then the use of diazo printing technique is of great interest since diazo copiers are available in almost every office. It has been found that by making use of adequate methods and material it is possible to make diazo prints with almost the same image quality as that attained in photographic contact prints. Then one prerequisite is to make a transparent screened positive copy on lithographic film. The best result is reached by using a positive screen with about 130 lines per cm. From this screened positive the best copies are made in semi-dry copying machines on so called contrast paper. A simpler and less expensive method is to print diazo copies from transparent ortho photo positives made on continuos tone film. Since diazo material is not made to reproduce continous tone originals the image quality is by no means excellent, but the result may be acceptable for some applications.

When ortho photos are needed in greater numbers the reproduction is usually performed by offset printing. Then it has so far been neccessary to use screened originals. Latterly the Land Survey has studied the possibilities to print continous tone material without the use of screening. Thus experiments with screenless lithography have been carried out with a special kind of printing plates (Howson Alympic). The utilization of this kind of screenless lithography has given good results especially concerning the reproduction of forested areas.

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