

EXPERIENCES FROM THE USE OF COMPUTER AIDED AERIAL PHOTOGRAPHY WITH GPS AT THE NATIONAL LAND SURVEY OF SWEDEN

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ABSTRACT:

This paper will briefly describe the work at National Land Survey of Sweden, NLS, with Computer Aided Aerial Photography (CAAP).

The work started in 1989 with some experiments in order to gain practical experiences of the GPS-technique in aerial photography and an understanding of the capability of GPS in that application. The first test was made in September 1989 at Gävle-Sandviken airport. Some experiments with kinematic GPS has been done earlier with good results. Also abroad tests with GPS supported aerial photography pointed at great advantages. A project was started in 1990 to establish a computer aided aerial photography production line with support from GPS. A system for planning, navigation, exposure control, postprocessing and archiving was developed. This system is beeing successfully used in the production of aerial photography from the season of 1991.

Firstly, a description of the system is given, secondly, some experiences achieved are presented and thirdly, a short discussion about advantages is presented.

Key words: Aerial photography, GPS, Navigation, Exposure control, System design.

THE CAAP SYSTEM, AN OVERVIEW

In a CAAP production line there are several parts of activities, however, four major ones can be observed:

- 1/ planning
- 2/ navigation and exposure
- 3/ postprocessing
- 4/ archiving.

In the CAAP system developed in the project these four parts constitutes four subsystems.

The principle of division is the chain of activities in the traditional production of aerial photographs. The chain starts with recording an order and ends with accessibility to the archive of aerial photographs. The subsystem for planning results in a data set containing preselected exposure points as input data to the navigation part of the system. In that subsystem the input data is used for navigation and exposure control. When a photography is taken a record of output data is created as input to the postprocessing. The postprocessing is divided into two parts. First, the production line of negatives, and second the photogrammetric line. Here only the first one, the production line of negatives will be dealt with.

In the postprocessing the data files collected in the navigation part are used to produce strip plans, key maps over the strips, and to mark the film (ie give identification to each of the negatives). During the flight season data is

stored in a temporary database. After the season, data will be organized and stored in an archive database. The archive database will be used to facilitate the work in the archive.

The whole CAAP system is built in a PC-DOS environment. Planning and postprocessing make use of a file server as host. The navigation software is installed at PCs in the aircrafts.

After this overview of the CAAP system, I will now give a more detailed description of the system.

Planning

During the season for aerial photography NLS has to produce aerial photographs for its own production of topographic maps and orthophotos. NLS has also a large production on recovery basis for municipalities, orienteering clubs and others. In the planning process all these orders are organized by altitude, film and area. In the subsystem for planning only an easy moment of creation of exposure coordinates has been added to the traditional planning process. To create coordinates for the navigation software a simple software was developed. The goal was that it should be very easy to use, and to be able to operate on IBM-compatible PCs. Therefore, no digitizing tablett is used. The calculation of exposure points is based upon starting and ending position of each strip, together with some other information. Either the base length, ie the distance between adjacent photo points, or the overlap in

percent can be given together with aerial camera parameters such as focal length and negative size, as input data to the software. For determination of the z-coordinate a mean height value of the area is calculated from the elevation database of NLS. The resulting data file is input to the navigation software. It is an ASCII data file, consisting of x-,y- and z-coordinates for each photo point. The file can be edited.

Every job is stored in a subdirectory. In the subdirectory the coordinate files are stored as well as an area file. The area file administrates what strips to be used, and in which order the strips will be numbered and drawn in the navigation software.

To check the input data, a plot is always made. For this purpose the AutoKA-PC software is used. AutoKA-PC is a mapping software developed by NLS.

Navigation and exposure

Equipment During 1991 one aircraft was equipped with the navigation system. The technical equipment consists of:

- Zeiss Jena LMK Aerial camera
- A portable PC as navigation computer
- Ashtech LXII GPS-receiver with photogrammetric option.

The system is shown in figure 1.

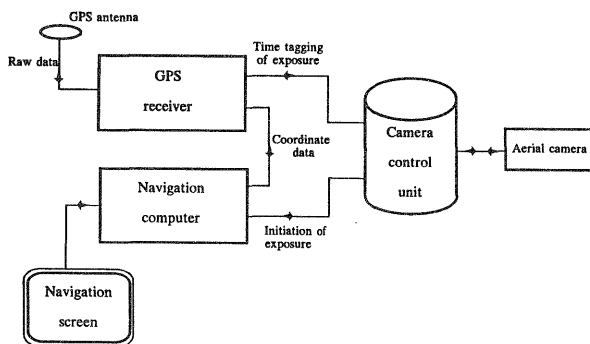


Figure 1, The navigation system

We have chosen not to connect the system to the autopilot. Instead, the navigation information is presented on a flat screen to the pilot and the navigator. They will control the flight visually. This solution was chosen to avoid change of direction of the aircraft when a photo is taken. During 1992, we added real time corrections to the GPS-receiver in order to obtain better accuracy of the real time navigation.

The navigation software The navigation software uses the satellite position as input coordinate data. The data is displayed as positions and as corrections on a screen, see figure 3. The navigator and the pilot use this information to navigate. The software controls the aerial camera directly. When the aircraft reaches a preselected photopoint, a pulse is being sent to the camera and a photo is taken. For each exposure a record of output data is

created, containing exposure identification, coordinates, height, satellite quality and time.

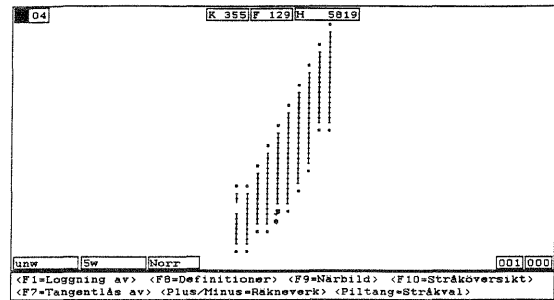


Figure 2, The area screen. This screen shows the strips of a job. A starting point is chosen by use of keys.

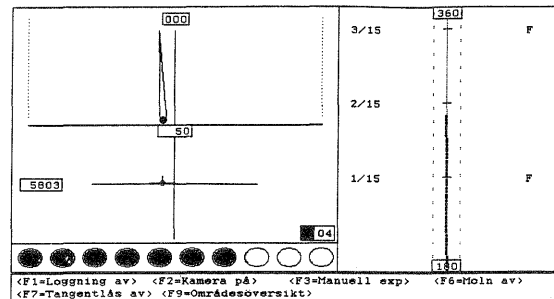


Figure 3, The strip navigation screen. The screen is divided into four parts. Top left is the prediction line, bottom left is the position in height and parallel to the strip, bottom centre is a downcount for exposure and on the right, a vertical indicator showing how the flight is proceeding.

The navigation software administrates the jobs in two ways. Firstly, the data of each job is stored as a subdirectory outside the software on the hard disk. Every job subdirectory consists of files containing coordinates of the preselected exposure points. Secondly, in the navigation software, selection of one job is done alphanumerical. The job will then be presented graphically on the area screen (figure 2). The software then uses the area file to extract, numerate and draw the actual strips during the particular job. On the area screen, a starting point of one strip is selected by use of keys. The navigation software will automatically give navigation information to the particular starting point directly after selection. When the aircraft is positioned at the beginning of the strip, the strip navigation screen will be used. This shows more accurate information of the position of the aircraft during the strip flight. The strip navigation screen is shown in figure 3.

At each preselected photopoint along the strip, a pulse is generated and sent to the aerial camera. The actual photopoint object will be flagged as taken and the object will then be erased from the screen. When the fiducial marks are exposed a pulse is sent to the GPS-receiver to tag the exposure time. This time tagging is very accurate, and it is also the key to accurate positioning of the

exposures in the postprocessing. To make this procedure possible, the raw data must be recorded. Together with the raw data, a protocol file is made. This will be used to evaluate control the flight after the mission.

Postprocessing

The postprocessing is divided into two parts, the production line of negatives and the photogrammetric postprocessing line. In the system design we observed these two parts, but only the production line of negatives is implemented so far.

The postprocessing is as follows. After a mission the film and a floppy disk are sent to the person who handles the postprocessing. The floppy disk is read and stored in the work database. In this database there is information stored about jobs, rolls and strips. The database is located at a file server and could be reached from several PCs at the same time.

The database is used in several steps. Firstly, a plot is made from the protocol file to check the result. This plot is used as a support in the optical check of the developed film. A bad result may be reason for a reorder.

Secondly, after acceptance, the film is marked. For this purpose the database is used together with a specially designed software and a plotter. The film will then be cut. An overview map is plotted. A printout of a selection of information from the database about the actual job is also made.

Thirdly, after acceptance, the negatives are sent back to the laboratory for the production of diapositives. During the inspection process some quality parameters are registered and stored in the database.

The job will then be delivered to the customer. The negatives are stored in an archive at NLS.

For the photogrammetric postprocessing, the outer projection centre for each exposure will be calculated. This will then be used in the aerial triangulation. This has not been done during 1991 since we do not yet use corrections from a reference station GPS-receiver. There are several ways of getting precise positions, but two of them are favourable. The best way is to get corrections directly from the radio. This will reduce the amount of data and therefore reduce the cost of postprocessing. The second way is to use a postprocessing method to get more accurate positions of the exposures.

Archiving

After the flight season (in Sweden, ie March 1 to September 1), the data is transferred to an archive database. The archive database is designed to archive of negatives at NLS. This archive contains almost one million negatives from the start of aerial photography in Sweden in the 30s. Today, this archive is handled totally manual. The archive database will be a geographical database where aerial photographs are searchable in terms of geographical space, flight height, film type, time, etc. It will be very time consuming to convert the manual register

to such a database. However, a minor study has been done, and a demonstration program using a cartographic interface and a phototype to an archive database has been developed (Ottoson, 1992). The system is running at a PC. This system will be used as a platform for further development of the archive system.

The geographical data to the archive database, will be collected in two ways. Normally, when CAAP system is used, data will be recorded automatically. If the system does not work, manual registration and digitizing must be done. Hopefully old data will be manually collected successively.

EXPERIENCES

The experiences from the CAAP system are divided into three parts and will briefly be discussed below. The experiences will be concentrated around the navigation software. First the experiments done by NLS will be described. Thereafter follows a summary of the implementation of the system and finally, there is a short description about the use of the system.

Tests

The experiments done by NLS are described by Jonsson and Jivall (1990) and Jonsson and Andreasson(1992). The first test made in September 1989 at Gävle- Sandviken airport aimed to determine the advantages and to get information about GPS-supported aerial photography. The test was done with a small Cessna aircraft where a Zeiss Jena LMK camera was mounted. The GPS receiver was an Ashtech LXII with photogrammetric option. At the airport, two GPS receivers were used as reference receivers. The results are the following:

- comparison between actual exposed and preselected positions was found to be 20 - 40 meters(ca 0.5 seconds) too late and the accuracy of an exposure at a preselected position was 6 meters (1 sigma) along the strip.
- comparison between relative carrier phase and photogrammetric positions was calculated. The agreement between the position was found to be about 0.15 meter per coordinate.

The results pointed at a possibility for a use of GPS in aerial photography. New tests of the same type were made 1990 with an ordinary aircraft, a Gulfstream commander 840. The results from the 1990 experiment were almost the same as in 1989. As a result from these tests, a decision was made that a system should be developed to handle GPS-supported aerial photography.

System implementation

The system has been implemented successively. First, a prototype software was developed and tested. The navigation software was first tested in a car and then in an aircraft. During the tests education was carried out. One

experience is, that education take a lot of time, much more than it was planned for. This small step by step approach of system introduction proved to be useful. Corrections were easily made.

The CAAP Navigation software in Production

The navigation system was successively installed during 1991. Tests have continuously been made within the ordinary production. As a navigation system only, without exposure control, the system was often used from July 1 to August. Yet, two percent of the photos in 1991 were taken with exposure control.

During October - November 1991 the system was fully used in aerial photography for the Kuwait-Iraq border demarcation. Analyses from this job show that the mean difference between preselected and actual photo position, obtained by aerial triangulation, was 11 meters with a standard deviation of 10 meters.

In 1992 a new version of the navigation software was introduced. The first use took place in Kuwait. Data from this job will be analysed during 1992.

Two aircrafts have been equiped for the flight season in Sweden. A newer hardware especially designed for moving vehicles is used. We hope that the system will be fully used during 1992. One problem is the SA, selective availability, ie degradation of accuracy. This has been swiched on after the Gulf war. Because of SA, the use of the system at lower altitudes without real time corrections must be carried out with the greatest caution. During 1992, also tests with real time corrections will be made.

ADVANTAGES

The advantages with the GPS navigation software are not only better navigation support but also better control of the flight in sense of exposure at preselected photopoints.

The exposure control makes it possible to obtain an optimization of the ground control points. The exposure control also makes orthophoto easy to produce.

It is, of course, easy to produce strip plans and key maps over the missions with computer technology.

In the future, the use of outer projection centre as input data to aerial triangulation, might increase the accuracy and reduce the amount of ground control.

SUMMARY

This paper has described the Computer Aided Aerial Photography (CAAP) system developed at the National Land Survey of Sweden. The system is used for GPS-supported aerial photography and be a foundation for further development.

Some of the experiences have been mentioned. The tests at NLS in 1989 and 1990, were the basis for the development of the CAAP system. The step-by-step introduction method and some jobs were made with the navigation software.

The advantages already reached are better navigation and exposure control in sense of getting exposures at preselected exposure points. This will facilitate the production of orthophotos.

In the future we hope that the GPS-supported aerial photography is a method to reduce the costs and to enhance the possibilities of digital photogrammetry.

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