A REAL TIME 3-AXIS COMPENSATION PLATFORM AND A GPS-BASED NAVIGATION SYSTEM FOR HIGH RESOLUTION AIRBORNE SPECTOMETERS

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PURPOSE

A combination of a 3-axis compensation platform and a GPS-based navigation system for high resolution airborne pushbroom spectrometers are discussed.

A Zeiss SM 2000 was tested on many flights and to be found ideal for practical use of image spectrographs, avoiding the data destructing influences of the scan lines.

While a spectrometer needs various navigation depending parameters to operate it properly, a flight navigation and management system was created which delivers the necessary flight control data automatically and facilitates the supervisory functions during the records.

KEY WORDS: 3-axis attitude sensor platform. GPS-based Flight Navigation and Management System

1. A 3-AXIS REAL TIME COMPENSATION PLATFORM

Since May 1990 my office is flying the Compact Airborne Spectrographic Imager (CASI), the first production unit of this instrument. During the first mission it became obvious that even in flight altitudes of 10 000 ft, where wind is much morer constant and even less, the roll affects the images and spectra of the spectrometer.

Only in very few cases those roll effects can be avoided. Even during optimum weather conditions a stable situation is never given.

Before the system was delivered I got several experiences by taking part in demo flights in Norway and Germany in 1989, being aware that the roll effects could be of major disadvantage for the results of the spectrometer.

So I was looking for a compensation platform from the beginning on. The manufacturer of the CASI was not able to deliver a compensation at that time. My choice was the Zeiss SM 2000 3-axis gyro stabilized platform used for the LMK-large format camera..

End of 1990 I made some experiments with my CASI on this platform. I could calculate that the platform should function well. Also some measuements showed the suitability of the instrument. The platform had to be modified in respect to its equilibrium to take the light weighted CASI spectrometer head.

Also some electronics had to be changed included a manual regulation of the yaw motion. The platform was intensively tested during CASI flights in the UK, and Germany in summer 1991.

Most of the images are accurately corrected and only in some cases rest motions are seen. Switching-on-off-tests also showed that the system was working properly.

The platform has a motion speed of 9 degrees/second which is enough to correct typical roll, pitch and yaw effects in usual flight weather conditions. In case of high frequency bumps, especially during hot summer days, the inertia of the platform prohibits a compensation ad shuts down immediately.

Flight altitudes in 10 000 ft are causing usually a larger angle of attack which is setting the platform out of function.
A wooden wedge of 5 degrees under the platform helps compensating the angle of attack sufficiently.

It happened that the platform lost oil at the first flight and later in between other flights, a diode burned off.

The first accident was due to oil leackage of the pump system and the second one due to a sudden generator voltage peek during a flight.

After these two events nothing happened furthermore and the instrument was even working properly after a longer standing over the winter time.
To get the platform functioning throughout a full line recording, it is necessary to reduce banking at the end of a run to enter the next run. Short and rough bankings are bringing the platform to its ends and shut it off. The gyros are slowly coming back to their position and therefore slight bankings by larger curves flown are necessary before entering a new run.

Additionally the CASI needs also a certain scan line tape streamer synchronisation, counting dark frames before coming into operation of a new run, provided for each run a new file is opened. Before entering a new run during the frame recovery time, a set back of the platform is necessary to its zero position by the manual motion test and turning the yaw to its zero position. Leaving it off, the gyros take their positions according to the motion of the aircraft. The drift can be directely read and it is also possible to tap the drift angle electronically from the platform and together with the indicated and corrected airspeed the ground speed and also the wind can be calculated. This was a major problem previously for full automatic navigation systems.

Various peripheral equipments were also mounted beside the CASI on the platform such as a 35 mm camera, a video camera, the Spectron hand held radiometer and a special telescope for controlling water reflections, shadings and waves (the CASI is mainly an instrument for water observations of any kind).

The platform makes it especially possible to worke with a second hand held radiometer to check the spectra against each other. This can be done without major expenses. The platform fulfills multiple purpose applications.

Gyro controlled roll angles to correct in postprocessing procedures have the disadvantage that the geometric position of the shifted line (of the pixel) is corrected to nadir or original perspective view, but not the pixel information of the slant range itself. It can be corrected by certain algorithms, such as illumination angles under various lines of sight or similar oblique views.

But for the natural objects this is not possible and remains an approximation. If one regards the low spatial resolution of the CASI, compared with a photograph, any additional manipulation on the image further degrades it. A real time compensation for those kind of instruments is mandatory.

2. A GPS-FLIGHT NAVIGATION AND MANAGEMENT SYSTEM CONCEPT

The present GPS-navigation systems for aerial photography have three primary functions:

- keeping track of the run by a CDI,
- delivering the time intervals for the exposures and possible drift angles to correct the drift.
- delivering coordinates for the principal point of the photos or for the total flight line

Spectrometer operations need much more parameters to control the records on a run. The manual recordings of these parameters are very tidious to carry out within a short time between the runs as many missions and flights were showing.

Therefore I decided to write a special software to carry out these operations automatically on a notebook computer, switched to a GPS-receiver (a GARMIN 100) and the CASI by the serial interfaces.

The system called SFNS (Spectrometer Flight Navigation System) is subdivided into 3 main functions selected by a menue:

- Base data entry
- Spectrometer in-flight navigation control
- Peripherals control

To calculate continously certain parameters during the recordings, base data have to be entered.

These data are collected before flying, from prepared maps and requirment sheets of the users. Two steps are performed for the base data entry. The first step contains primary spectrometer data such as the location of the runs, the run number and names, the spectrometer mode, spatial or spectral, the mode parameters, such as bandsets and looks, the required integration time, the required air speed, the ground resolution and the MSB.

After having typed in these base data, they are stored in a file under the project and site number or name and a second window opens automatically for digitizing the borders of the area to be flown together with the start and end points of all the runs.

The digitized coordinates are converted into geographical coordinates by map control points from the respective map used and appended to the base data file. This procedure is carried out for all the sites flown in a mission.

The primary submenue is the in-flight nav. and management screen on which all graphical and data displays are appearing during the flight.

A typical in-flight operation display is the following:

Approaching the site and the runs to be recorded by the spectrometer, the project, site number or name and the run number are called from the disk of the notebook computer. Then the in-flight nav.-display screen is called which shows all base data included the local situation graphically.

Entering the local spectrometer data, such as aperture according to light conditions and possible changings of altitudes and air speeds due to local weather conditions and other weather depending parameters, the GPS-coordinates are called from the receiver and the aircraft position is displayed in relation to the area on the notebook screen. The continous approach is displayed and all changing data is calculated such as the distance to cover to the first start point, the rest time to be used to the start point, the bearing, the ground speed and the continous time in UTC.

Shortly before entering the first run the ground speed is controlled by the scan factor (which is the ratio of the required ground speed to the actual ground speed), the most important value for getting non expanded or non-shrinked images (data loss).

The scan factor must be nearly 1.0. The approach of the aircraft is seen on the display and as soon as the aircraft is entering the start point of the run within a certain tolerance circle, the spectrometer is switched automatically via a pulse over the second serial interface. Then the nav.-data of the run is continously displayed and the GPS-coordinates of the run also stored. There is no need to store a coordinate each second. It may be enough to store a coordinate all 5 or 10 seconds due to the applications.

If a camera is connected to the serial interface of the notebook computer the exposure intervals can be also given, synchronized with the frame pulses of the spectrometer.

A frame pulse counter displays the number of frames taken from the start point on. Reaching the end of the run, the spectrometer switches off and the data are fully stored and certain data are averaged and all are appended to the base data file.

A new run is called in case of multiple runs to be recorded. All runs of a site are flown in the same way and data stored on the notebook computer.

At the airport the spectrometer image- and spectral files are calibrated and the nav. and spectrometer data files are read into an ORACLE/INFORMIX SQL-database. The nav. and spectrometer data can be written as hard copy outputs, on floppies or appended as header or trailor files to each image or spectral file of a run.

Data are written to video8 tapes. 9-track tape transfers are not written any longer, as they appeared very circumstantial and uneconomical for a spectrometer such as the CASI.

3. CONCLUSIONS

With the described real time attitude platform and the spectrometer flight nav.- and management system, a simple, operational and economical solution for the CASI-spectrometer is achieved which in this status does not even need a further development, because it fulfills all requirements for the practice of the spectrometer operation during a flight.

The operator is free from any manual recordings of nav. data during the flight and can concentrate on image and spectra quality, observing illuminations and environmental impacts on the records and control the crucial problem of the speed-integration time relationship by the scan factor in cooperation with the pilot.

For the case no GPS-signals are received the manual recording system is still working and also no flight is performed without the traditional nav.-sight telescope and a third crew member as navigator on board.

Relying on pure and high tech is silly and as flight experiences are showing one has to count always with the worst case, surprises and accidents in aircraft operations.

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