OPERATIONAL ASPECTS OF DIGITAL AERIAL MAPPING CAMERAS

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ABSTRACT:

With the introduction of the new aerial digital mapping cameras, the operational aspects for aerial photo flight projects will change. New task, like digital image data handling and data copy in the filed will be implemented into the workflow. Instead of a film, digital data will be shipped and archived. The camera operators and the crew have to get familiar with the new work steps. The Z/I Imaging DMC Digital Mapping Camera System is used as an example to explain the operational procedures and the data workflow.
To set up a proper mission planning the required GSD ground sampling distance has to be determined. Referring to the traditional film camera, this is a combination of photo scale and scanning resolution.
After a photo flight mission the digital film has to be developed. The airborne mass storage device with the raw image data will be removed from the aircraft to the office, where the image data post processing will take place. If the crew is away from the home base on an outbound mission and has no access to the post processing workstation, the image data will be copied from the airborne mass storage device to a different media, like removable hard disk drives or tapes. The handling of this process has to be full automatic to reduce time and costs and to reduce the stress for the crew. To get the camera ready for the next mission as quickly as possible is an important factor. The data copy can either be done in the aircraft or in the hangar or hotel room.
The digital cameras are offering new possibilities for on-site quality checks. A first image data quality evaluation can be done in the air during the mission. Especially for areas with air space restrictions this will be a big time and cost saver.

1. INTRODUCTION

With the introduction of the new aerial digital mapping cameras, the workflow for aerial photo flights will change comparing to the traditional way with film based analog cameras. Also the way to specify surveying flight project will change from photo scale to ground sampling distance. This is a challenge for the camera operators and for the project managers. New skills will be required to deal with the mass of digital image data. Image archiving will require new technologies and strategies. This paper will explain the new methodology and workflow using the Z/I Imaging Digital Mapping Camera DMC as an example.

2. FLIGHT PLANING

Usually the photo flight starts with the mission planning. A digital mapping camera thinks in ground samples distance (GSD) or ground resolution and not in photo scale. The flying height, the focal length and the pixel size of the CCD sensors are the parameter used for the calculation. For frame based cameras like the DMC, side overlap and forward overlap for stereo coverage follow basically the same rules like for film cameras. Because there is no consuming material used, like for the film cameras, we will see more projects planned with higher overlaps like 95% / 80%. For true orthophoto generation especially in urban areas this high overlaps will be used more and more.
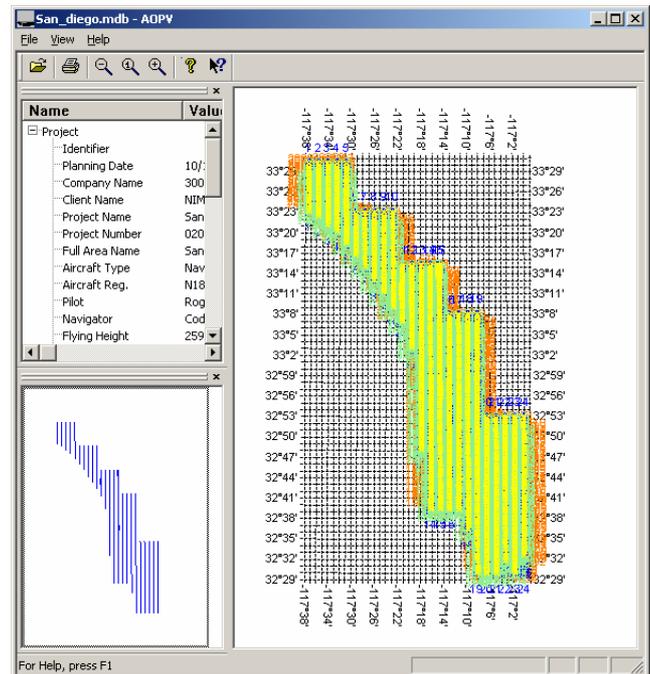

Figure 1 Flight project overview

ISMP ImageStation Mission Planning software is a modern tool for photo flight mission planing, based on MicroStation, raster backdrops can be displayed to support the user. The ISMP software is a stand alone product, but it is also part of the DMC system.

3. CAMERA OPERATION

The camera operation of a frame based digital camera like the DMC is very similar to the operation of an analog camera. The film magazine is replaced by a ruggadized mass storage unit, which can be, in case of the DMC, exchanged in the air during the flight to extend the capacity, like swapping film rolls. A new generation of flight management systems like the Z/I ASMS Airborne Sensor Management System controls the camera system and provides information for the pilot on a display in the cockpit. The disk capacity of the airborne mass storage is usually enough for a full day mission. A big advantage is that the camera operator can have access to the acquired image data between the flight lines or during the flight back for the mission to the air field. This is a huge benefit against film cameras because it allows a real time image quality assessment. But this is only true for frame sensor based cameras not for push broom or CCD line sensors based cameras.

The camera operator can have access to the acquired image data through the onboard computer equipment. A image data post processing for one image can be done in a few minutes even with limited computer performance, this is one of the biggest advantages of frame based cameras against line sensor cameras. For a first image quality check GPS and IMU data are not required.

Frame sensor cameras are not depending on this technology, it can be used optional. Although today modern professional aerial photo flight will not be executed without the use of precise GPS information.
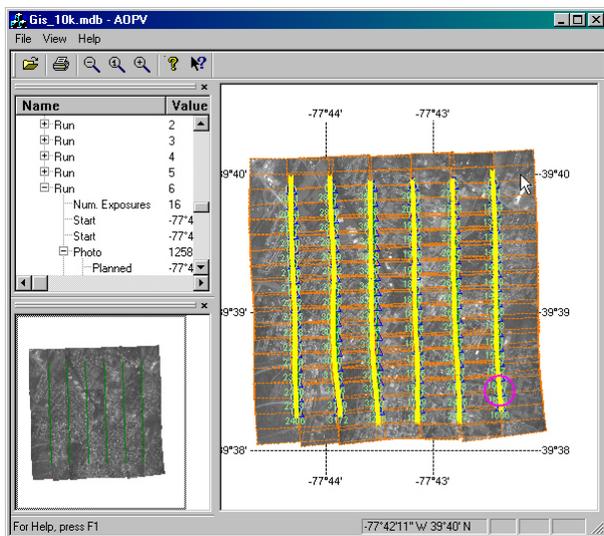

Figure 2 AOPV airborne on-board project viewer

To maintain the quality for a photo flight, information about cloud coverage is very important. Therefore the ASMS (Airborne Sensor Management System) has an integrated video camera. The video camera displays the image scene during the time the exposure is taken. A video thumbnail pertains to each exposure, the thumbnails can be mosaicked to an overview to get an impression of the complete mission. The camera operator can then easily identify each exposure where the cloud coverage was to much and mark these images for second shot.

This new functionality is a huge benefit and cost saver for the photo flight project. The crew can decide in "real time" without leaving the mission area, if there is a need to repeat a flight strip or to re-fly single images.

A huge benefit of modern aerial sensor management systems is a high level of integration to reduce the number of external devices for the aircraft. For example the ASMS hardware includes the camera control interface, the control interface for a gyro stabilized camera mount, a video frame grabber board, a L1/L2 24 channel GPS receiver and an interface to the POS 510 control electronic (IMU for direct geo referencing)

Figure 3 ASMS Aerial Sensor Management System

4. DMC DIGITAL MAPPING CAMERA

The Digital Mapping Camera DMC is a new frame based large format aerial camera, designed for high precision large scale engineering application as well as for small scale mapping projects.

The DMC uses a CCD frame sensor with a 12 micron pixel size, which means 144 square micron of light sensitive area.
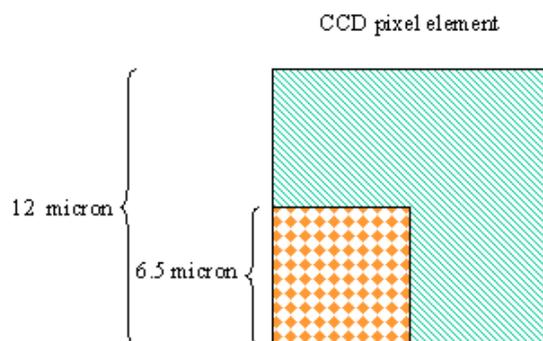

Figure 4 light sensitive area of a CCD pixel element

It is the nature of a CCD that the light sensitivity increases straight linear with the light sensitive area, which means that a 12 micron CCD is approx 3.5 times more sensitive comparing to a 6.5 micron CCD.

Because of it's multi sensor multi spectral design the camera also fits perfectly for remote sensing application, like forestry analysis or agriculture monitoring.

The DMC is a wide angle camera with a focal length and a field of view similar to a RMK TOP 15 film camera.

The highest benefit of the new digital camera technology will be an increase of the flying hours per day and the flying days per year because of it's higher radiometric quality comparing to film. It will be possible to fly under worse light conditions or with lower sun angles and still fulfill the quality requirements of the mapping standards.

Since the mid 80's a forward motion compensation FMC is used for aerial film cameras to improve the image quality and to avoid image blurring. Nowadays all aerial survey flight projects required a camera system with FMC. Because of the frame sensor technology the DMC has an implemented electronic FMC, which is a huge advantage and not possible with CCD line sensors. A time delayed integration TDI is used to generate the FMC. For large scale mapping project or for photo flights with long exposure time (weak light conditions) a FMC is a perquisite.

For high resolution four 4k x 7k CCD frame sensors are mosaicked to a large format image frame with central perspective and very stable interior geometry. The final image size is 13824 x 7680 pixel. The footprint of this image has the same width of a film based aerial image (across track) and approx 60% of the length (along track, in flight direction). This is a very important information, because the number of flight lines will remain the same comparing to a film camera and so the flying costs.

The DMC is a "Cessna 206 class" camera, which means the system will fit into the majority of all survey aircraft in use with respect to it's power consumption and it's size and weight. A user can fly the camera in a single engine aircraft.

The aircraft installation is pretty much the same as for a film based camera like the RMK TOP. A DMC will fit into all aircrafts modified for 9.5" film cameras.

5. FDS FLIGHT DATA STORAGE

To store the raw image data during the photo flight a reliable powerful mass storage device has to be part of the system. For further data processing the handling of this device has to be very user friendly. The DMC camera system is using flight data storage unit FDS, three units are required for a system, each FDS can store 250 GB of data, which means in total 750 GB, equivalent to 2200 aerial images.

The FDS uses standard high speed fiber channel interface technology, it will be installed in the aircraft with a base plate, usually mounted to the seat rails of the aircraft.

The size of one FDS is the same as the size of a small tower PC, the weight is approx 20 kg, the power consumption is 60 W. The FDS can be installed and removed without disconnecting cables and without using any tools. It will be automatically powered up and down by the DMC camera module. If multiple FDS's are available, an exchange will be possible in the air during the photo flight to extend the storage capacity.

Figure 5 flight data storage unit FDS

The FDS has a very reliable and ruggadized design, it contains two SCSI hard disk in a hardened pressurized enclosure. It can be operated up to 5000 m or 16000 ft (8000 m or 26000 ft are optional available) flying altitude in an non-pressurized aircraft. The FDS is extremely robust and shock proofed, data safeness is absolutely assured.

For image data post processing the FDS can be connected directly to a workstation in the office via a standard fiber channel interface.

The FDS is a flexible and versatile data storage system, designed for airborne operation.

6. DATA HANDLING IN THE FIELD

After an aerial photo flight mission is completed the crew has to "develop" the digital film. Very often the airplane is on an "outbound mission" where the crew does not have access to the ground based post processing facility or the airplane has to get ready for the next mission as soon as possible. It will be required to download to raw image data to a removable media. To perform this task Z/I Imaging had developed a mobile field data copy station. This copy station can be taken on-site by the crew with the aircraft and used in the field for data copying.

With the copy station the raw DMC image data can be downloaded from the onboard mass storage device to a removable media like hard disks, USB disk drives or tape drives. The user can copy the data either in the aircraft, in an office or hangar at the airfield or in a hotel room. The computer is equipped with 3 fiber channel interfaces to connect the 3 flight data storage units FDS and to ensure a high data transmission rate. A full set of FDS with approx 2200 DMC images can be copied in less than 4 hours to removable IDE disk drives. The copy process runs in batch mode , which reduces the interaction with the operator.

After the copy process is completed, the media e.g. removable hard disk drives will be shipped to the home office like an undeveloped film.

The copy station can also be used as a utility for on-site image quality inspection. Software tools are provided to perform a quick view of the acquired image, the radiometric image quality can be evaluated immediately. This is a benefit against the film based camera, because the user does not have to wait for the film development and gets an immediate feedback on the success of the mission.

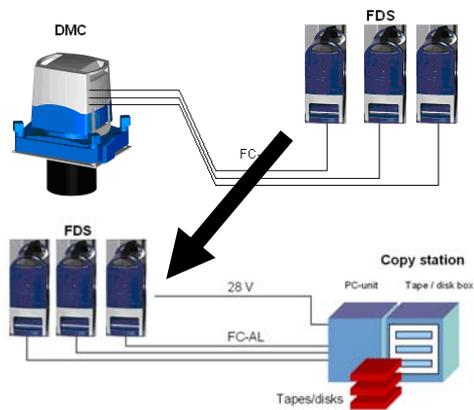A block diagram should illustrate the data flow.

Figure 6 Flight data storage connected to the copy station

There are possibilities for the future to include parts of the post processing with the data copy process or to split up the data of one photo flight mission into several projects, which might be sent to different users.

The digital camera system offer a wide variety and flexibility of image data handling to speed up projects, to reduce costs and to improve quality.

Figure 7 DMC field data copy station

7. DATA POST PROCESSING

Digital aerial cameras are requiring Data Post Processing to create the final output image from the raw data acquired during the flight. There is a big difference for this post processing between the different camera architectures like line based and frame based sensors.

7.1 Line Sensor Cameras

For digital cameras based on line sensors the main challenge is to correct the distortion of the individual lines, there is a geometric shift between each line caused by the aircraft movement. This correction requires precise information about the external orientation of the sensor during the time of exposure usually provided by an IMU Inertial Measurement Unit. Before an user can start with the image post processing,

the GPS/IMU data post processing is necessary. Without this data, the image post processing can not be done.

To achieve an acceptable post processing time, massive computer infrastructure (CPU farms) is required. From an economical point of view there is a high threshold for the minimum workload to get a reasonable return of invest.

7.2 Frame Sensor Cameras

Frame sensor based cameras have a straight forward way for the image data post processing by using standard photogrammetric algorithms. Because of the stable X-Y sensor geometry, GPS/IMU data are not required to create the final output image. The post processing time is much shorter comparing to line sensor cameras. The software is running on standard workstations and is not requiring any special computer infrastructure.

This is a huge benefit of the DMC, fast image data post processing. With a standard high performance workstation (e.g. dual 2.4 GHz XEON CPU with 1GB RAM) the raw image data can be processed, no special hardware, no special environment and no special computer facilities are necessary. All camera calibration data, geometric and radiometric calibration, will be provided to the user on a CD. This data will be used at the time of the image post processing.

With a minimum level of user interaction the software automatically post processes the raw image data into the final frame. The output format can be specified, multiple formats like RGB and CIR can be created in parallel. Probably the biggest advantage of the new digital aerial camera against traditional film cameras is the immediate image access. It is possible to get high resolution color imagery or color infrared images within 24 hours after the photo flight.

8. REFERENCES

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