SYSTEM CONFIGURATIONS AND SENSOR ARCHITECTURES

Digital Aerial Cameras - Product Survey

This issue of GIM International provides an extensive product survey on digital aerial cameras. In support of the specifications provided by this product survey, this article presents additional information on system configuration and sensor architecture of camera systems from nine manufacturers.<P>

The general benefits of digital aerial over film cameras include better radiometric performance and elimination of film processing and scanning costs. Availability of image content in digital format enables a highly automated workflow, creating the possibility of generating photogrammatric products such as orthophotos/mosaics with little delay between capture and end-product. This might allow, for example, for rapid response after a disaster.

Linear and Area
Twelve-bit-per-pixel radiometric resolution, or even higher, ensures better light sensitivity. The use of image enhancement techniques means details can be made visible in parts of the imagery made bright by reflections or overcast and dark due to shadow or cloud. This relative insensitivity to unfavourable light conditions enables extension of the daily time-span during which images can be taken, and of flight season. It also allows data collection on overcast days, thus optimising aerial survey productivity and area coverage. Basically, the architecture of a digital area camera consists either of linear CCD arrays or area CCD chips placed in the focal plane. The linear-array architecture, also called the pushbroom scanner, principally employs a single lens head. Colour (or multi-spectral band capture) is obtained by placing three or more linear arrays in the focal plane, upon each of which are projected different parts of the visible and near-infrared electromagnetic spectrum. Beam-splitters are used for this. The area CCD array solution is camera architecture consisting of several (multi-head) cones. Since linear- and area-array solutions are the most important features of camera architecture, the camera systems from various manufacturers are grouped accordingly.

AREA ARRAY

Applanix
The two Applanix Digital Sensor Systems (DSS) consist of completely integrated medium-sized digital camera, GPS-aided INS direct georeferencing system (POS AV) and flight-management system software for generating orthomosaics (Figure 1). POS AV provides the exterior orientation parameters in both real-time andpost-mission mode. Although primarily used to generate high-resolution colour and colour infrared digital orthophotos/mosaics using POS AV data and an existing Digital Elevation Model (DEM), the system also supports full stereo imagery for DEM extraction and visualisation. The data interfaces directly and seamlessly with photogrammetry software to allow for fast map production. The DSS 322 array measures 5,436 pixels across and 4,092 along the flight line (in total 22MP); for the DSS 439 these figures are 7,216 and 5412 pixels respectively (39MP). The pixel size of the DSS 322 is 9um and of the DSS 439 6.8um, so that the field of view of both is the same. GSD ranges from 3.3cm to 1.0m, depending on platform and using 40mm and 60mm lenses. The DSS system sensor heads weigh about 7kg; they are thus medium-sized and presented by the manufacturer as complementary to large--format digital cameras. They can be flown in small, low-cost, light aircrafts or helicopters. The camera systems were certified in September 2007 and are to date the only medium-format system to have been qualified by the US Geological Survey (USGS) as a metrically stable mapping grade system (see GIM International September 2007 for USGS Quality Assurance Plan for Digital Aerial Imagery). The application areas vary from updating and maintaining cadastral databases to rapid response for disaster management.

DIMAC Systems
Each camera of the DiMAC system acquires one RGB or one near infrared image via one CCD (7,216x5,412 pixels, pixel size 6.8?m) through one lens. The lens may be one of three focal lengths: 55mm, 80mm or 120mm. GSD ranges from 2cm to 1m. The Camera Cylindrical Frame (CCF) allows for combining up to four camera modules (CM). A light architecture may be constructed using just one camera in the CCF; but two cameras (CM1 and CM2) may also be placed here, creating a RGB image of slightly less than twice 5,412 pixels (10,500 pixels) by 7,200 pixels. Two additional CMs may be placed in the vacant holes, resulting in an image of 10,500 by 14,400 pixels. Another configuration is formed by adding a Near Infrared in CM2 covering the same area as that in CM1, or by placing a 55-mm Near Infrared camera in CM3 covering the same area as CM1 and CM2 together.

IGI

With dimensions of 10x13x12cm and weighing 1.8kg, the IGI DigiCAM system is a medium-sized system which combines modified professional digital cameras with a graphical user interface for real-time preview together with the CCNS/AEROcontrol. Two or more DigiCAMs can be coupled to increase image size. Each 39 MP area CCD chip (7,216x5,412 pixels) pixel is sized 6.8μm. Camera settings are adjusted by checking quick-views and histograms of images in real time. For pre-planned flight missions the camera is triggered by the CCNS4 system. Determination of exterior orientation parameters is done using the AEROcontrol GPS/IMU system, each capable of monitoring one or more cameras mounted in a pod. In the case of multiple cameras, synchronisation can be carried out within a few microseconds. Each of the two storage units onboard can store 1,800 images in 16-bit colour and full resolution and be exchanged during flight to extend storage capacity. Standard units may be replaced for high-altitude flights by flash memory units with 1,150-image capacity. The DigiControl computer itself does not operate any hard disks. The lenses include (maximal aperture/focal length): 4.5/300mm, 3.2/150mm, 2.2/100mm, 2.8/80mm, 3.5/50mm, 3.5/35mm and 4.0/28mm. The modular design enables a change from RGB mode to colour-infrared within minutes for all lenses. The maximum image repetition rate is 0.52 images per second; a higher rate can be reached for a small number of subsequent images ("burst mode").

Intergraph
The architecture of Intergraph's Digital Mapping Camera (DMC) amalgamates eight individual CCD array camera modules into autonomous units. Separate lenses are used for each of the eight camera heads, and a rigid optics frame ensures precise alignment of the optical axes. Four of the eight camera modules are equipped with 120-mm lenses and capture panchromatic images on four area-CCD chips 7,000 by 4,000 pixels. The other four cameras simultaneously capture the three colour bands (RGB) and the near infrared band on 3,000 by 2,000 CCD chips. The multi-spectral cameras are equipped with 25-mm lenses (wide-angle).

Microsoft/Vexcel
The Vexel UltraCamX camera consists of sensor unit, onboard storage and capture system, operators interface panel, a removable data storage unit and software to operate the camera and for processing image data after flight. The sensor head comprises eight independent camera cones, four contributing to the large-format panchromatic image and four to the multi-spectral image. The sensor head is equipped with thirteen CCD sensor units, each producing 16MP. This set of lenses also supports a pan-sharpening ratio of 1:3. The storage system contains two independent data units for redundant image capture, each replaceable by spare units within a few minutes. Downloading of image data is supported by a docking station which exploits four parallel data-transfer channels to allow complete data transfer of 4,000 images within eight hours. A 24-hour cycle of flying, copying and QC can be achieved.

RolleiMetric
The Aerial Industrial Camera (AIC) series from RolleiMetric is designed for aerial and industrial purposes and is presented by the manufacturer as an alternative to large-format cameras. The camera body (electronic) and the lenses are Rollei products; the focal lengths of the medium-format lenses are 50mm, 80mm, 90mm, 120mm and 150mm, while the pro lenses have focal lengths of 35mm, 47mm, 60mm and 72mm respectively. Both are optimised for photogrammetric use, with fixed focal length and stabilised bayonet. Their high-speed iris shutters, up to 1/1,000 second, enable compensation for forward motion during flight. Pro lenses are symmetrical lenses designed for digital-camera sensors and small pixel size; they allow high-resolution imagery and minimise colour aberration. The focal plane contains Kodak RGB CCDs (22MP or 39MP) with Bayer pattern and IR cut filters fronting the sensor. Filter change allows acquisition of images in RGB, NIR and CIR. RolleiMetric carries out geometric calibration and Phase One executes radiometric calibration of the sensor. The camera electronically controls all settings such as shutter speed, aperture and black calibration from the PC, and interfaces with IMU/GPS systems (event signal) and FMS (trigger signal). The AIC xN architecture allows joint fitting of up to eight standard AICs in one frame, using electronic boards for accurate synchronisation and Daisy Chain connections. All AICs are in full communication with each other. The AIC x2 combines two cameras and the AIC x4, four. Depending on desired overlap, the footprint may cover up to 13,000 x 10,000 pixels.

LINEAR ARRAYS

Jena
The Jena Airborne Scanner (JAS 150s) is based on pushbroom (linear-array) technology. The GSD width depends on flying height and its length on flight speed. To preserve (almost) square pixels sampling, there are 29 exposure times ranging from 1.25ms, that is 800Hz sampling frequency, to 10.112ms and four binning modes so that eight pixels may be combined into one. This allows great flexibility in selecting aircraft height and speed. Four sub-systems take care of command and control, data recording, position and orientation, and flight control. The system is also equipped with an interface for on- and offline quality control of the raw image data, so that each sensor-line may be checked onboard the aircraft during flight. Setting of all camera parameters, such as exposure time, drift input and INS-system command, as well as control of camera status parameters, can be done during flight. With an accuracy of up to 3cm at 1,000m altitude, full resolution in multi-spectral images, including CIR, can be captured.

Leica-Geosystems
ADS40 second-generation Airborne Digital Sensor from Leica-Geosystems produces linear-array sensor images. Two sensor-head configurations are available: SH51 offers multi-spectral imagery and panchromatic stereo imagery with 100% forward overlap for orthophoto production, and SH52 produces fringe-free stereo imagery in panchromatic, colour and near-infrared and simultaneously captures 115 MP per second across twelve CCD channels. The temperature-stabilised telecentric lens, focal plate and IMU carrier are fused into one block, ensuring stability of calibration over long time-spans. Combining single-lens design with the newly patented Tetrachroid beam-splitter technology reduces energy loss and enables the production of co-registered five-band imagery at equal resolution, thus eliminating the need for pan-sharpening. Leica IPAS10, the integrated inertial position and attitude system, allows direct geo-referencing to sub-pixel accuracy. Depending on accuracy requirements, image data can also be processed without use of ground-control or reference stations. Applications include orthophoto production, featureextraction and remote sensing.

Wehrli
Wehrli's 3-DAS-1 system consists of three cameras, each equipped with 110mm lenses and mounted on a stabiliser, an inertial measurement unit (IMU) firmly attached directly above the cameras and a GPS antenna the lever-arm to the gimbal centre of which is fixed in distance but not in attitude. The nadir camera faces downwards, the forward camera is tilted by 26 degrees and the backward

camera by -16 degrees in the direction of flight with respect to the nadir camera. Each camera has three linear CCD arrays for colour imaging. These belong to the Kodak family of KLI trilinear (RGB) CCD arrays and feature 8,002 pixels and pixel size 9x9µm. Rather than attempting the use of a single, exotic objective lens to cover the entire field of view over the forward, nadir and backward-looking arrays, a separate objective lens is used for each of the three cameras. The software runs on Windows XP or Vista. The scanner electronics is in firmware and thus upwardly mobile to keep pace with technical developments and future requirements. Transfer of image data from the sensor electronics to the computer is by Camera Link standard, at 12 bits, to a PCI-X 64-bit line grabber. The camera link also provides a control channel and download of new firmware.

Acknowledgement
Thanks are due to all listed manufacturers of digital aerial cameras.
