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A Computer Based Camera Control System

The system controls up to four small-format, non-metric cameras of three different types.

Introduction

The evolution of aerial photography from hand held cameras in balloons and light aircraft to complex metric camera systems and solid state sensors in large and specialized aircraft was accompanied by large increases in hardware costs and corporate and government specialization in aerial photography.

Within the past two decades, interest in small format, non-metric aerial photography has developed as a result of increasing costs of aerial photography (Ulliman, 1975) and developing research selblad cameras (Doyle, 1970; Kammerer, 1973); Woodcock (1976) used a Leica 35 mm camera with a Hasselblad; and a number of other researchers have used a variety of 35 mm cameras (Fisher and Steever, 1973; Giannelia and Rafelson, 1979; Meyer, 1973; Whittlesey, 1975; Zsilinszky, 1968, 1972).

The emphasis in most articles has been to describe the camera system and respective aircraft mount and to demonstrate the suitability and cost effectiveness of such systems. Only one article describing a camera control system appears in the

Abstract: *Increasing interest in non-metric multi-camera systems and decreasing costs of portable computer systems makes a computer based camera control system attractive. The described unit was specifically designed to increase accuracy, improve reliability, and lessen operator workload compared to simple intervalometer controlled and manually operated multi-camera systems. The major attraction of a computer based system is the ease with which it can control complex camera combinations and other remote sensing equipment.*

potential in multi-scale, multispectral aerial photography. Since Aldrich *et al.* (1959), *Photogrammetric Engineering and Remote Sensing* has published more than the twenty-two such articles listed in the references. In aerial photography applications, a 70 mm film format has been most popular, as has been the Hasselblad 500 EL camera. However, Carneggie and Reppert (1969) used two Maurer KB-8 70 mm cameras; Spencer (1978) used two Vinten 70 mm cameras; Lyons (1967) used a Hasselblad from a helicopter; the Apollo missions used a variety of modified (metric) Has-

major journals (van Eck and Bihuniak, 1978) although a number have mentioned or discussed simple intervalometer or radio triggering systems (Sabins, 1973; Ulliman *et al.*, 1970; Whittlesey, 1970, 1972, 1975; Zsilinszky, 1968).

In addition to such camera systems, a series of articles has appeared dealing with the photogrammetric and interpretative qualities of non-metric aerial systems. Articles on photogrammetry include Faig (1976), Karara (1976), Karara and Abdel-Aziz (1974), Kolbl (1976), Nasu and Anderson (1976), and van Wijk and Ziemann (1976).

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Clegg and Scherz (1975) dealt with photointerpretation comparing 9 inch, 70 mm, and 35 mm photography. Other articles on combined-system interpretation include Spencer (1978), Woodcock (1976), and Zsilinszky (1968, 1972).

A number of articles have considered focal-plane shutter distortions; of particular relevance to non-metric cameras are those of Abdel-Aziz (1975), Aldred (1968), and Nielsen (1975). These papers follow a series of related articles dealing with film distortions in non-metric cameras.

The above research has tended to reflect the generally increasing acceptability of and confidence in the use of non-metric systems. Routine use of small-format, generally non-metric cameras has demonstrated specific problems in reliability. These include inadequate power supply, mechanical failure, and system interconnection problems in control and timing of multi-scale, multispectral, mixed camera combinations.

The System

Aptech Integrated Technology Ltd. was contracted by the Ontario Centre for Remote Sensing (O.C.R.S.) to design and build a multi-camera control system that would control up to four cameras of three different types. (Vinten, Hasselblad, and Nikon.) The system would also power these cameras and eliminate the need for batteries in the Hasselblad and Nikon units. This was considered especially important for the Hasselblad cameras as the batteries had proved to be a principal source of unreliability in routine aerial reconnaissance.

The unit was designed to increase accuracy of photo coverage and stereo overlap while maximizing film economy; improve system reliability through the use of direct power supply and (in the case of the Hasselblad 100 foot magazines) monitoring film advance; and decrease operator workload by providing a single analog control and viewing screen with a microcomputer interconnection to calculate (see Appendix) photo intervals and trigger cameras for all job requirements including multi-scale, mixed camera combinations.

Figure 1 shows a block diagram of the present system. The equipment contained within the dotted line is packaged inside the computer, a Commodore PET 2001. The computer supplies a contact closure signal to initiate a camera picture-taking cycle. The special relay requirements of the Nikon and Vinten cameras are provided by a relay box at the camera mount.

The system can be controlled during flight from either the local keyboard and display or from the remote keyboard and video display, located in the O.C.R.S. aircraft at the co-pilot position.

A television camera located in the camera mount produces the ground image that appears on the monitors. The system generates a center line to assist in drift correction, a moving-bar display that is synchronized by the operator (using the grid speed control box) to the speed of the ground image, and computer messages regarding system performance, flight documentation, and camera combination in use.

The remote display with center line may be used by the pilot as a drift sight to ensure that the aircraft is directly over the correct flight line. The speed of the moving bar is used by the computer to determine image speed for interval calculation.

Figure 2 shows the installation in the aircraft, a Piper Aztec, used by the Ontario Centre for Remote Sensing.

Because the grid display is generated electronically on the same screen as the ground image, there is no viewing parallax error.

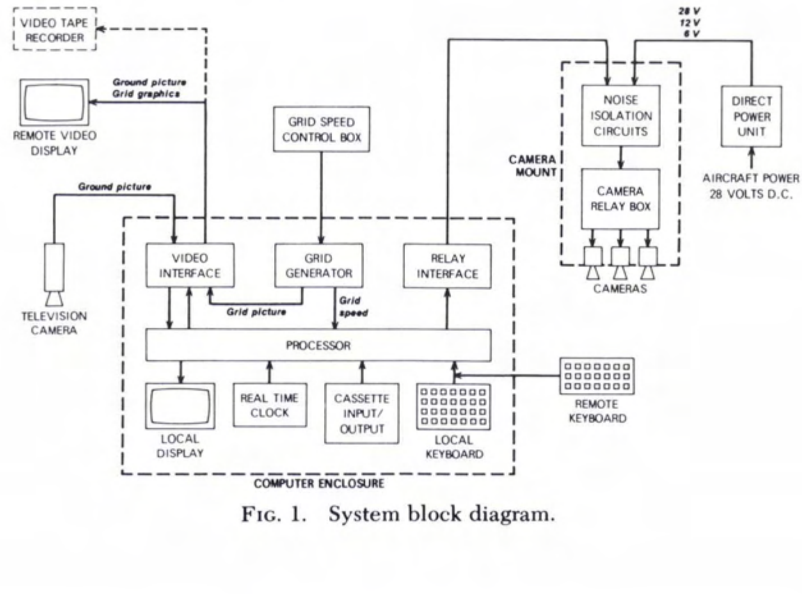

FIG. 1. System block diagram.

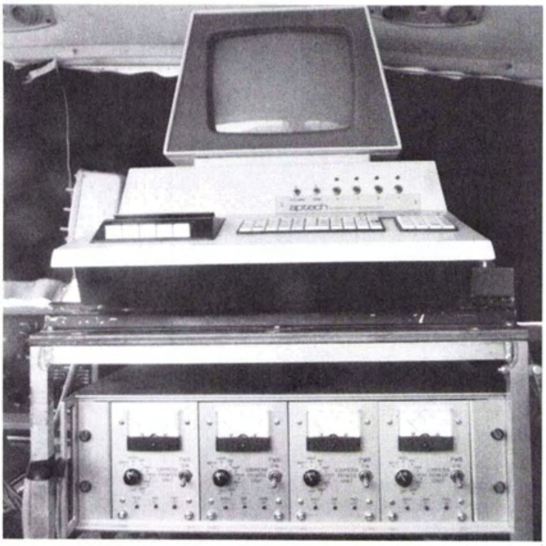

FIG. 2. Camera control system and power modules as installed in the O.C.R.S. aircraft (courtesy of Ontario Centre for Remote Sensing).

Computer messages are called up under operator control and include (1) number of frames taken by each camera, (2) calculated interval for each camera, (3) overspeed warning when the computer attempts to cycle the photography faster than the camera's mechanical limit, (4) indication of system readiness when parameters are changed, (5) time of day in hours/minutes/seconds, and (6) readout of camera parameters for each task (i.e., lens focal length, film format size, percentage of desired overlap, type of camera, and television camera focal length).

The language used to program the system is BASIC. This language is capable of responding immediately to keyboard commands and will request missing information. BASIC has good editing capabilities, and is a relatively simple language for inexperienced programmers to learn. This makes program development or modification a matter that can be handled by the system operator. A modification to the existing program that will enable the display of a lens field of view on the video screen is currently being developed by the O.C.R.S. operators, Alex Giannelia and Michael Rafelson.

The BASIC interpreter includes a random-number operator, which is useful for random sampling during image acquisition.

Simultaneously with the timing of the photography, the program must perform a number of service operations associated with monitoring the keyboard for operator input and writing the display readouts. Because BASIC is an interpreter rather than a compiler, programs written in it are activated relatively slowly; also, these service operations cause a random error in interval of about 0.2 seconds. (The computer program includes an error-minimization routine to ensure that the error distribution is centered on the desired interval.) This interval error restricts the minimum interval to about one second, which is adequate for the present range of applications.

For shorter intervals in this system, the Vinten and Nikon cameras can be put into "runaway" mode, in which the camera cycles at its own speed. For the Vinten, this is 4 to 12 frames per second and for the Nikon, between 1 and 5 frames per second. The Vinten relay interconnection includes a selector switch for single-shot operation under computer control, single-shot operation by pushbutton, low-speed runaway mode, and high-speed runaway mode.

For shorter intervals under computer control a timing circuit, set by the computer, could be used.

The direct-power unit modules shown in Figure 2 accept 28 volts from the aircraft and generate 12 volts for Nikon and 6 volts for Hasselblad cameras. They monitor the 28 volt, 12 volt, and 6 volt lines using a front panel meter and selector switch to check for voltage and current malfunctions. The system protects the Nikon and Hasselblad cameras by limiting their fault currents to 0.6 and 1.8 amps, respectively, and indicates when fault current is flowing in the 21 and 6 volt lines by illuminating LED indicators.

Each module will supply one camera of each type, simultaneously if necessary. Four are used in this system and a fifth module is used with a 28 volt battery and charger to bench test cameras.

The flow chart for the entry of computer data is shown in Figure 3. Before a flight, the computer program that configures the computer as an intervalometer is loaded from cassette. The program asks for the relevant data about camera focal lengths, percentage overlap, film formats, and

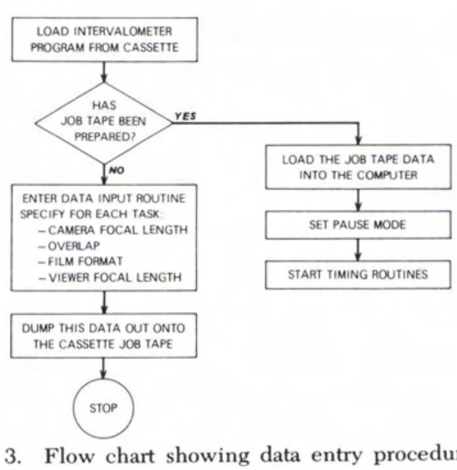

FIG. 3. Flow chart showing data entry procedure for system.

viewer focal length for each task. This information is then recorded on a JOB cassette. The computer may then be shut down for the flight to the target area.

Over the target, the intervalometer program is again loaded, and then the JOB tape is loaded. As the first flight line is approached, the operator uses the display center lines as an aid to rotate the camera mount so that the cameras are aligned with the flight line. The moving bar is adjusted to coincide with the speed of the ground image. The program is activated at the beginning of the flight line and the system begins taking photographs at the correct intervals. Multi-scale, multispectral aerial photography can be routinely obtained using the system. Correct coverage is ensured, and non-productive air time due to calculation errors and equipment malfunction is minimized.

Discussion

The computer system has capabilities beyond its present use as a control system for multi-scale, multispectral camera combinations. These are discussed below and include

- Control of solid state remote sensing equipment, including the setting of control parameters;
- Accepting and interpreting data from remote sensing instruments and triggering cameras or other equipment in response to those data;
- Performing random and other sampling operations; and
- Maintaining a continuous and up to date applications flight log, materials inventory, and equipment usage log.

Where a control function is required by some solid-state sensor, this may be provided by the computer in this system. Hardware interconnection may be accomplished via the computer IEE-488 access, its 8 bit input-output access, or its memory expansion access. Software control may be accomplished using the BASIC PEEK and POKE instructions, in order to examine data from or send data to an external device.

For example, the computer could be used to interrogate a radar altimeter and continuously indicate height above ground on the video screen. With a film annotation unit in each camera, it would be a relatively simple matter to program the computer to write radar altimeter data or other data on each frame. The altimeter signal can also control camera triggering for specific scale requirements.

With the capability of the computer for analysis in real time, the computer could be used to analyze data from a multispectral scanner. A specific spectral signature could be used to trigger cameras to document forest damage and thus a selective and relevant sample is acquired, minimizing processing and interpretation while recording the location for remedial action. If only necessary imagery is obtained, the interpretation task is reduced and the time to find the result is shortened. Stringham (1974) points out that the sheer volume of imagery to be processed and interpreted is often the major delaying factor in aerial photography and remote sensing applications.

The existing system is capable of random sampling. This is especially important when only a small but representative sample of an area is required. Once the statistical requirements of a sampling program have been established, a simple program can be written to trigger the cameras at the appropriate intervals.

The same computer used in the camera control system is frequently used in business inventory applications. It could be used in this system as an electronic log for film use, sensor history, and photo flight records. A printer is available for hard copy output of this type of data, or to provide hard copy of recorded sensor data.

Acknowledgment

The system described was designed and built by Aptech Integrated Technology Ltd., Toronto, Canada in collaboration with the Ontario Centre for Remote Sensing, Ministry of Natural Resources, Toronto, Canada.

Appendix

The Intervalometer Equation

Velocity of image movement in camera is related to that in viewfinder by

$$V_C = V_A \times \left[\frac{F_C}{F_V} \right] \tag{1}$$

where V_C is velocity of image in camera in mm/sec,
V_A is velocity of image in television camera in mm/sec,
F_C is focal length of camera in mm, and
F_V is focal length of television camera in mm.

Distance between frames is given by

$$D_{NO} = S_F - D_O \tag{2}$$

where D_{NO} is non overlap distance in mm,
D_O is overlap distance in m, and
S_F is size of image in direction of travel in mm.

Now,

$$D_O = \frac{O_V}{100} \times S_F \tag{3}$$

where O_V is percentage overlap from frame to frame. The time between frames, T seconds, is equal to distance of image movement in camera divided by velocity of image movement. i.e.,

$$T = \frac{D_{NO}}{V_C} \tag{4}$$

Substituting from Equations 1, 2, and 3, we have

$$T = S_F\left(1 - \frac{O_V}{100}\right) \times \frac{F_V}{F_C} \times \frac{1}{V_A} \qquad (5)$$

Velocity on television monitor screen V_A' is related to V_A by

$$V_A' = \frac{L_D}{L_C} \times V_A \qquad (6)$$

where L_D is size of television monitor display and
L_C is size of television camera image area-length in the direction of travel.

In this system, L_C = 6.6 mm and L_D = 140 mm.

Substituting from Equation 6 into Equation 5 for V_A, we have final expression for interval:

$$T = \left[S_F\left(1 - \frac{O_V}{100}\right) \times \frac{F_V}{F_C} \times \frac{L_D}{L_C}\right] \times \frac{1}{V_A'} \quad (7)$$

Values of film size, overlap, camera focal length, and viewer focal length are entered before a flight and the quantity inside the square brackets is computed. This is then treated as a constant for each camera, thereby reducing the computational requirements, during picture taking, to an evaluation of V_A' and multiplication by the appropriate constant.

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