THE ASP2000: A NEW ANALYTICAL PHOTOGRAMMETRIC INSTRUMENT

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(A description of and the logic behind the development of a new analytical stereoplotter.)

ABSTRACT

The ASP2000 is an analytical photogrammetric instrument based on the mechanical and optical layout of the QASCO SD-4. The electronic control system has been completely redesigned to make use of components which are now available as a result of the rapid development of technology for personal computers (PC's) and the stepping motor drive system has been replaced by high speed DC motors with encoder feedback. The instrument now has a resolution of one micron, and a slewing speed of 40 mm per second. CCD cameras and special hardware for digital image correlation have been incorporated in the basic design, together with facilities for image superimposition.

This paper discusses the changes in the drive system, and the philosophy of the new software both in the host computer, and in the instrument itself.

1.0 INTRODUCTION

In mid-1987 Adam Technology took over the SD-4 project from QASCO, and commenced work on the development of a large format instrument using the experience gained on their MPS-2 analytical system.

The SD-4 had been designed in 1980 as a simple, compact, low-cost analytical instrument with a least count of 6 micrometres. It was driven by stepping motors under the direct control of a M6809 computer system within the instrument itself, managed by a DEC PDP-11 computer running under the RT-11 operating system. The DEC system performed the calculations to transform from ground position to plate co-ordinates, and these values were transmitted to the SD-4 by a serial line running at 9600 baud.

The ASP2000 has been been provided with two computer systems which carry out all the transformation calculations formerly handled by the DEC equipment as well as controlling the drive systems, and hand controls.

This relieves the host computer of all critical real-time processing loads and allows either a PC to be used as a host computer, or the instrument can be part of an interactive graphics system such as "AUTOCAD". The function of the host computer is to provide a graphical interface with the operator, compute transformation parameters, and log data on to output devices such as the graphics screen, an X-Y plotter, and disk files.

The standard ASP2000 package includes software for calibration, interior and absolute orientation, data files and menus, and overall systems control. Additional software is available for the observation and adjustment of blocks of photographs, and other special purpose software can be supplied on request.

Programs for communication with the host computer, for photo stage control, and for fast real-time transformations between machine, plate and ground co-ordinates, are incorporated in read only memory (ROM) associated with the microprocessors in the stereoviewer hardware. These programs are available immediately the system is powered up but calibration and transformation tables must be loaded from the host computer before a digitising session can commence.

1.2 BASIC DESIGN ARRANGEMENT

1.2.1 Drive System

The original stepping motor drive system for the SD-4 had been chosen because it was a reliable control system which could be managed with an eight bit microprocessor. However, stepping motors are not very efficient, and have relatively high power requirements even when they are stationary, and this limited the maximum speed of the main drive systems.

Small high performance DC motors with an optical shaft encoder attached are now readily available, together with special controller chips to handle the feedback loop, and these were used as the three main drive motors. The small stepping motors in the delta-Y systems were retained as they were adequate for their task.

The ASP2000 is approximately 800 mm long, 550 mm high, 450 mm wide and weighs approximately 45 kg. A central scanning carriage runs along two horizontal guide shafts which are mounted one above the other in a steel space frame. The carriage is located on the shafts by linear races and is moved horizontally along the shafts by a precise recirculating ball screw assembly.

Optical heads are mounted on vertical guide shafts on each side of the carriage. They are located by means of linear races, and moved by recirculating ball screws. These three main drive systems are now driven by DC motors which replace the stepping motor systems of the SD-4.

The mechanical components have been designed to provide good repeatability, and final accuracy is achieved by the control software applying corrections to compensate for any small systematic mechanical errors. The microprocessor systems and power supplies are mounted at the rear.

1.2.2 Optical System

Each optical head has a moving lens controlled by a small stepping motor to apply y-parallax correction. The drive system for this is now similar to the X-Carriage assembly in the MPS-2, i.e., the lens mount is guided along small guide shafts by linear races and moved by a recirculating ball screw driven by a small stepping motor.

The floating mark optical unit is mounted on top of the carriage, a binocular eyepiece is mounted on the front of the space frame, together prism systems for splitting light off to the CCD cameras, and introducing light from the image superimposition system.

The photo carriers are mounted within lighting boxes on each side of the unit. A coarse kappa adjustment is provided for the left photo carrier, and a coarse "bY" adjustment for the right carrier. These controls are used to initially "baseline" each stereopair, and so keep the bY corrections within the range of the delta-Y drive system.

Light passes horizontally from each lighting box through the area being observed on each photograph. The rays on each side then travel through a Y-parallax lens before being reflected by a front silvered mirror vertically to a beam splitter on top of the carriage. The beam splitter reflects the light rays horizontally towards an objective lens in the binocular eyepiece system, and introduces the floating mark image.

In photogrammetric terms, the main carriage motor provides a common "Y" motion with the moving lens in each optical head correcting for Y-parallax. The motors on the bottom of the carriage provide separate x motions for each photo of the stereopair.

In front of the binocuular eyepiece system is a small chain of prisms to enable vision to be direct, or crossed, or allow binocular vision on one plate. This chain also splits light off to two CCD arrays, and introduces the image for superimposition.

1.2.3 User Controls

Control of the unit is caried out from two "panniers" each connected by a short cable to the main unit. One pannier has a control for X and Y motion, four function switches, and toggle switch linked in parallel to a footswitch to indicate when data are to be stored. The other has control for Z motion only and each pannier has controls to vary the light intensity of its floating mark, and the sensitivity of the hand controls.

1.2.4 Electronic System

The electronic system in the ASP-2000 is mounted at the rear of the stereoviewer unit together with its power supplies. The control system consists of two general purpose micro-processors and a numeric data processor. In keeping with the philosophy used in the MPS, Intel processors were chosen. The ASP-2000 uses an 80286 processor (as used in the IBM AT PC) as the controller. This processor handles all communications to the host PC, performs all the real time transformations using an 80287 co-processor and directs motor operations via an 8088 slave processor.

The 80286 and 80287 processors update the plate co-ordinates 100 times per second, using a rigorous perspective projection together with corrections for lens distortion, earth curvature and calibration constants. Lens distortion values are computed from a polynomial, and the calibration data is kept in 5 tables each having 256 elements. The tables are for X-left, Y-left, X-right, Y-right, and the delta-Y system.

The 8088 processor performs all the motor controlling functions, reads the joysticks, handwheels and function buttons. The 8088 communicates with the 80286 via a full duplex high speed 8 bit parallel bus.

All the electronics to drive the ASP2000 reside on a single circuit board. The circuit board is a superset of the standard IBM PC plug in expansion board size. The processor board plugs into a motherboard which emulates the IBM PC bus. This enables standard PC compatible peripherals to be added to the system.

The system uses three DC servo motors with integrated encoder units. These are each controlled by a specialised motor control IC, the HCTL-1000 which performs feedback controlled motor positioning. The 500 slot encoder on each motor gives a resolution of 2000 steps per revolution. The lead screws have a pitch of 1 mm giving a resolution of 2000 steps per mm, or 0.5 microns. A RS232 serial interface is provided on the circuit board for communication with the host computer. The transmission speed can be set by switches on the board.

1.3 SOFTWARE FEATURES

1.3.1 Design Philosophy

The SD-4 software was designed so that a non-expert could use the system with minimal training. For example, it was not necessary to provide the approximate co-ordinates, or orientation for camera stations, and the user was led through each stage in the operation by prompts from the screen. The use of a PC has allowed more facilities in screen formatting, and the MPS software made extensive use of colour and "windowing" to assist the operator.

After extensive discussion with users, it was found that the principal dissatisfaction with existing systems lay in the way that the software led the user through one predetermined path and did not provide for the user to divert along the way. For example, when carrying out an absolute orientation, the user may find that the co-ordinates of a control point may have been omitted. In this case it would be desireable to stop observing, enter the values, then continue on. To cater for these needs, the design structure of the ASP2000 software was changed to provide maximum flexibility, while still keeping the operation as uncomplicated as possible.

Few operators bother to read and study the contents of operation manuals, and there is nothing more frustrating than having to continually refer to a manual to find out what to do next while operating a piece of equipment. At the same time the skilled operator will be annoyed if the screen is cluttered up with unnecessary information. To overcome this problem each field to be entered has a prompt to indicate what the user should enter, and most fields have a sensible default value so that the user need not enter anything in those fields. A "HELP" key is provided to give additional information as needed, and this will "window-in" appropriate information for that section of the process which is currently being performed.

The system uses a small number of files to store job information, and the number of files and quantity of digitised data that may be accumulated on any one or more jobs is limited only by the storage capacity of the host computer. The user can define feature codes to facilitate the production of final plots on an X-Y plotter with or without the intervention of post-processing graphics packages such as AUTOCAD and PALETTE.

1.3.2 Software Portability

The host computer software has been written for a PC running under the MSDOS operating system. The programs are written in FORTRAN77 and can be transported to other types of computers using different operating systems. There are two libraries of subroutines, one containing general purpose routines for mathematical manipulation and screen formatting, the other contains routines to communicate with the ASP2000. Most of the routines in each library are written in FORTRAN, with some of the routines written in assembler language to make better use of the facilities on a PC. The routines in assembler are mainly those associated with screen formatting, graphics and some of the routines used to communicate with the ASP2000. To transport the software to a different type of computer system requires changes mainly to those library routines written in assembler. The software has been written in a highly modular fashion in order to facilitate easy maintenace and to allow "application" routines to be added with a minimum impact on the standard software. A layered approach has been adopted in the standard software to enable the user to easily interface to the machine at the appropriate level.

1.3.3 Transforms In Stereoviewer

Since the real time perspective transformations are carried out using microprocessors within the stereoviewer itself, the PC is mainly used as a means of communicating with the stereoviewer, and as a system for storage and output of data.

During the orientation process the PC records the observations, calculates the model transformation parameters and sends these parameters to the stereoviewer. Thereafter the stereoviewer controls the model and sends ground co-ordinate values to the PC which records them on a disk file and controls output to an XY plotter and graphics screen.

1.4 SOLUTION TO ORIENTATION

The interior orientation can use up to 10 fiducial points, and the user can select either an affine or helmert transformation. Alternately, for cameras which do not have fiducial marks, the operator can select points along the edges of the frame, and a solution will be computed by fitting the frame shape to the points measured. Exterior orientation can be computed as a relative, then absolute orientation using the collinearity equation solution, or it can be by a rigorous bundle solution which can include a variety of parameters as control.

The results of the orientations are stored in the job file as well as being transmitted to the stereoviewer. This means that the model can be re-setup at a later date by repeating the interior orientation.

1.4.1 Lens Distortion

Allowance is made for both symmetric and asymmetric distortion using constants derived from the lens calibration program. A polynomial is used to compute a set of corrections at selected positions on the photograph. As the system operates these corrections are computed 100 times per second and applied to the photo co-ordinates.

1.4.2 Disk Files

There are four basic types of disk files used by the software. The correction file ASPCOR.DAT is created by the test and calibration software and is loaded into the stereoviewer at the start of a days session. It is in ASCII format and contains corrections in microns for the main drive systems and the y-parallax drive systems.

The job file contains all the initial parameters for a job such as flying height, lens details, and control information. The data is in in ASCII format and can either be manipulated by the data entry program which displays each record in menu format, or small changes can be made with a standard text editor.

The work file contains the results of the orientation procedure for each model together with details of the control used, and the parameters adopted in the digitizing phase. This allows a model to be re-set with minimal work (interior orientation) and digitizing to continue where it was left at a previous session. It also facilitates the automatic assembly of data for block adjustment. The file is in binary format.

Output files of digitized data can be in ASCII or binary format, and provision is also made to output files in special formats for post processing with various interactive graphics systems.
The data may be in the form of strings of co-ordinates preceded by an identifying header block, or it may consist of individual co-ordinates each with identifying codes. The actual final structure of output files can be determined by the user, and standard routines are availale for storing data such as roads, contours, sections etc.

1.5 CONTROL OF THE STEREOVIEWER

1.5.1 Modes of Operation

The stereoviewer can be directed to operate in comparator mode or in orientation mode. When in comparator mode the programs deal with a theoretical machine able to move two optical heads each in two directions, x-left, y-left, and x-right, y-right. All movements are in millimetres in each of these four directions. If a calibration table has been loaded into the stereoviewer, its values will automatically be applied and the same applies for lens distortion parameters. In this mode it can be considered as a "perfect" machine, that is, that the co-ordinates received need no further corrections.

When in orientation mode, the transformation parameters are also applied, and three dimensional co-ordinates are sent back to the host computer. The units depend on the transformation values, and movement is controlled using the X, Y, and Z motion controls.

In addition the operation of the F1 switch can be set so that either the right, or the left stage can be moved with respect to the other. The delta Y drives can also be turned off and this feature is used in the calibration routines, and in the pre-orientation procedure.

1.5.2 Communication With The Stereoviewer

Routines which can be called from FORTRAN programs are provided in the library MPCOMM to send and receive data from the stereoviewer, as well as set the operation mode and download parameters. The software automatically checks the identity of the stereoviewer to make sure that it is running compatible software, and all data transmission indicate if they have been successful or not. Data between the systems is in the form of ASCII characters with checksums and multiple retrys are made before a failure is flagged.

1.6 FACILITIES TESTING THE SYSTEM

Software is provided for checking the accuracy and repeatability of the ASP measuring system using standard grid plates. Routines are provided both for the calibration of the delta Y drives, and the main drive systems.

Observations may be performed in the normal manner or the operator may be replaced by a CCD camera mounted at the eyepiece and connected to a special circuit board within the PC. This second system eliminates personal errors in the observation procedure, increases the overall accuracy, and greatly reduces the effort required.

1.7 SUMMARY

The rapid development of the PC, and the ready availability of powerful microprocessor chips has enabled the ASP2000 to be developed as a relatively low cost analytical instrument with high performance, and high precision. It makes full use of the design configuration of the SD-4 to ensure stability of operation despite its size and portability.

The use of a PC as a host computer not only reduces the overall cost, but enables the software to be very "user friendly" and so opens up the use of photogrammetry to be spread into many new and diverse fields.

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