

## A CCD EYEPIECE FOR ANALYTICAL PLOTTERS

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### ABSTRACT

A measuring system has been devised to allow automatic calibration and performance checking of analytical instruments. It can also be used to assist the interior orientation process. The system comprises two small optical units each of which fits between an eyepiece ocular and its mount. The units are designed to direct the image to a CCD camera as well as to the eyepiece. Software has been developed for instrument calibration as well as for the measurement of fiducial and reseau grids.

KEY WORDS: Accuracy, Analytical, Calibration, Image Matching, Plotter

### 1. Introduction

There are some routine operations in photogrammetry which can be performed far more efficiently by simple image reading systems. These include the interior orientation process and the routine calibration and testing of instruments. In each of these processes grid crosses can be observed by a CCD camera system which is programmed to "lock on" to each cross and then refer that position to the analytical plotter. Ideally such a system should operate whenever the operator requires it, and should not interfere with the normal observing process.

In addition there is often a need for more than one person to view the model and this is best performed if a image of the operators viewpoint is displayed on a video monitor. While the more highly priced instruments have "built-in" video systems, there is a need for a relatively inexpensive system which can be slipped into existing instruments to be used where necessary. In effect, the unit can take the place of the dual optical systems which were available as an option on some analogue instruments, however the "CCD Eyepiece" is far more versatile because it is both a digital and a video image.

### 2. Design Description

The basic design concept is for two optical units to be placed in the viewing system to divert some of the light to CCD imaging modules. Each unit is fitted into an eyepiece instead of the final ocular, and the ocular is then attached to the back of the unit. The camera is attached to the side of the unit, and lenses and a beam splitting cube are used to direct the light paths. A diagram of the system is shown in Figure 1.

Within each unit, the top and bottom lens system is used to transfer the image plane so that the ocular can observe it above the beam splitter. The beam splitting cube diverts some of the light through a lens to a CCD camera, and the camera lens is selected to give a suitable magnification of the image to match the pixel separation of the camera.

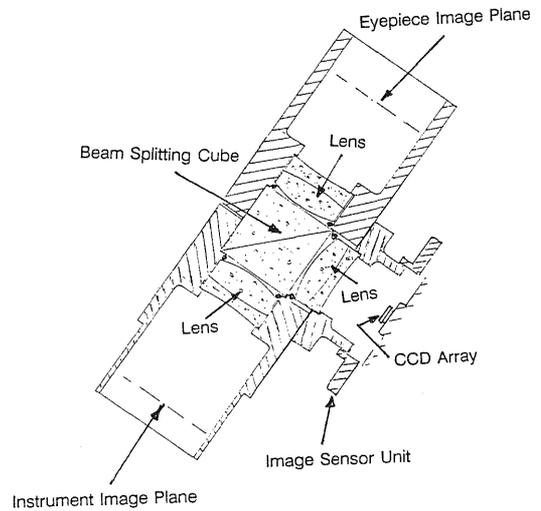


Fig 1. CCD Eyepiece Optical System

The test system uses a Phillips 56470 (CCIR) monochrome imaging module which has a 6mm X 4.5mm image area, and 604 X 588 pixels. This camera unit is very compact, and its electronic units can be folded out to lie parallel to the body of the optical unit as shown in Figure 2.

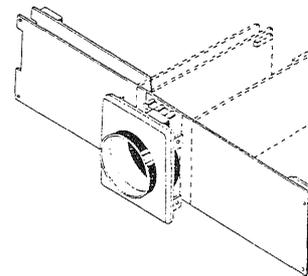


Fig 2. Phillips Imaging Sensor

The image modules are connected to a "PCVISIONplus" framegrabber which a single board unit that plugs directly into an expansion slot in an IBM PC. It digitises the incoming video signal to eight bits accuracy at a rate of 30 frames per second and has provision for two video inputs, and storage for two 512 X 512 images on the board.

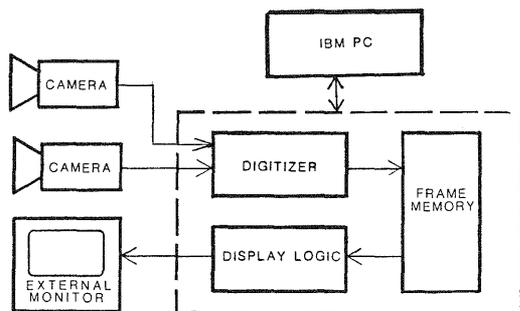
### 3. Method of Operation

To mount the units, the observer removes each ocular and slips in an optical unit, then replaces the ocular in the top of the unit. The image can then be viewed through the binoculars in the normal way, or via a video monitor so that pointing can be either directly through the system, or by looking at the video monitor. The floating mark is visible on the monitor, and the scale of this picture depends on the lens systems used in the unit.

The pixel values for each image can also be displayed on the computer monitor as numerical values or as a series of grey scales.

The cameras are connected to a frame grabber board which is mounted in a PC, and the software both sends instructions to, and interrogates this board to extract digital data as needed.

The frame grabber board has sufficient memory to hold one frame of data from both cameras and is controlled by instructions from the PC. The signal to the video monitor also comes from the frame grabber, and the picture displayed can be selected to be from either camera.



Components of a Digital Image Processing System

Once set in sampling mode, the frame grabber operates independently of the computer collecting and storing data from each camera 30 times per second. Because of its independence, the board can be mounted in the same PC which controls the analytical plotter, without degrading the performance of the system.

To establish a reference position within the camera, the main illumination is first dimmed, and the position of the floating mark established by finding the centre of gravity of the illuminated dot. If the instrument has to be refocussed, or the zoom setting changed, then this reference has to be re-established.

### 4. Data Analysis

While the problem of locking on to a cross may seem trivial, several problems arise to complicate the process. Essentially the task is to find a cross from a pattern which may include considerable background noise, and if the lines of the cross are very fine (those on the ADAM MPS-2 grid plates are fifteen micrometres wide), then there is not only background noise, but the cross itself can break up since the lines can be less than two pixels wide. The pixel size is determined by the magnification of the system, and the lens system used for the camera. A balance has therefore to be taken between having a very narrow field of view and a fine pixel resolution, and a wider field of view and a coarse pixel resolution.

With a five micrometre spacing, and a CCD array of 512 X 512, a window of two and a half millimetres views the photograph. Therefore, the initial pointing has to be within half a millimetre to guarantee that the system will locate each cross.

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0 0 0 0 0 0 0 0 0 0 1 2 10 8 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 7 0 0 0 0 0 0 5 11 10 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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0 0 0 0 1 5 0 0 0 0 0 0 9 12 5 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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0 0 0 0 0 0 0 0 0 0 0 0 2 12 9 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 10 18 10 2 0 0 0 0 0 0 0 0 0 0 0 0 0
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2 5 1 2 5 8 4 1 7 15 21 22 22 28 25 19 14 13 15 8 0 2 2 3
4 3 5 7 13 13 15 16 14 20 18 26 33 33 27 16 15 16 18 19 20 18 14 4
6 0 0 0 3 5 7 9 12 13 22 29 33 34 23 18 25 16 9 7 13 7 4 7 8
0 0 0 0 0 4 0 1 1 9 12 18 20 18 16 9 8 8 6 0 0 0 0 0 0 0 0
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Typical "Cross" as seen by the CCD Eyepiece (after the background has been removed)

The process used to find the centre of the cross is to along each row in the X direction to locate cross, and then repeat the process in the Y direction for the other arm. Each intersection point is found by selecting a group of three pixels with a minimum total weighted value, and then a parabola is fitted to these three points to find the centre of the arm of the cross. Checks are made to eliminate points near the centre of the cross and groups of points which are too wide to be part of the arm of the cross. A line is fitted to each set of points with "off line" points being eliminated, and these two lines are then intersected to locate the cross centre.

After the cross has been located, the offset from the floating mark position is calculated, and instructions sent to the analytical plotter to move to this new position. The cross is again located, and if necessary a further shift is made to centre the cross.

Several factors prevent simply computing an offset to the current plate co-ordinates rather than shifting the stage until it is centred. The spacing of pixels in low cost CCD cameras may not be regular and is often different in the X and Y directions. The scale of the image at the camera depends on the zoom factor which is currently set in the optics and the orientation of the CCD array with respect to the plate co-ordinate system depends on how it is placed in the eyepiece. The software has a "learning" routine to refine initial transformation parameters as it operates. If a number of moves have to be made to centre a cross, then the software automatically determines new values for the transformation parameters from the movement path of the camera. In this way, centring is achieved in a minimum of moves without the need to calibrate the cameras, or even know the pixel spacing and orientation.

## 5. Application Areas

### 5.1 Interior Orientation.

The quality of the interior orientation directly affects all subsequent operations, and if a reseau has to be observed there is a "trade off" between the number of grid crosses and the practical considerations of the measurement processes. Ideally the greater the number of crosses, and the greater number of pointings to each cross, the better the solution. Unfortunately, observer fatigue may in fact nullify the benefit if there are too many pointings, and any error in the measurement of a reseau cross is reflected in the accuracy of the subsequent data acquisition process. There is also the practical problem of the time for setting up each stereo pair if a large number of reseau crosses has to be carefully measured for the interior orientation.

With the CCD Eyepiece, the operator first dims the photograph illumination so that the position of the floating mark can be registered in the cameras, then an approximate pointing is made to each cross with the system carrying out the fine pointing. If the interior orientation program is designed to drive the stages to each fiducial, then the operator only has to provide coarse pointing for the first two points, and the rest of the operation can be totally automatic.

### 5.2 Instrument Calibration

Instrument calibration is generally performed from grid plate measurements with patterns of 25 or more points being measured for each stage. To get some measure of reliability, each point should be measured at least four times and this requires at least 200 pointings for an instrument. Any testing for stability requires the calibration process to be repeated many times over a lengthy period, and in such circumstances operator fatigue is likely to affect the results.

The process with the CCD Eyepiece is similar to that used for interior orientation, and the position of each grid plate cross is stored so that the instrument can drive to each cross automatically and observe the point.

The automatic calibration process has two main advantages: it enables prolonged testing to assess the stability of a machine over time; and it provides an impersonal assessment of actual performance.

### 5.3 Education and Teaching

In this area the monitor can be used so that a class of students can follow exactly what the operator is doing, and concepts of X and Y parallax may be quickly understood. We have found that the whole processes of orientation can be more quickly understood if a class follows in detail the work of a skilled operator. In addition, when a student is operating the instrument, the supervisor can follow in detail each operation and so advise in a constructive fashion as the work proceeds. This type of operation does not require a frame grabber system, although the ability to display pixel values as well as the video image can be useful in some teaching applications.

### 5.4 Photo interpretation

This type of work often requires discussions about different data points as well as comparison with other data. While the video display is showing the photographic image, the computer screen can be displaying another data set and if required this data can be merged with digital information from the photograph. While such a system cannot provide "real-time" superimposition in the actual eyepiece, it can provide a relatively inexpensive method of image superimposition for existing instruments.

## 6. Conclusion

The CCD eyepiece system provides a method for extracting a digital image from existing analytical and analogue equipment. If combined with software for automatically locating targets such as crosses or points, then the system can greatly facilitate the testing and calibration of instruments, as well as the interior orientation process.

The system provides a means for displaying the observer's view of the photographic image on to a video display, and this can be used to advantage in both teaching and in photo interpretation work.