The Cambridge Automatic Plate-Measuring Project

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The Cambridge automatic plate measuring project is an attempt to develop a reasonably cheap system capable of measuring photographic images to sub-micron accuracies at high speed, typically 10 images/sec.

The system may be considered to be an encoding device controlled by an on-line computer. A

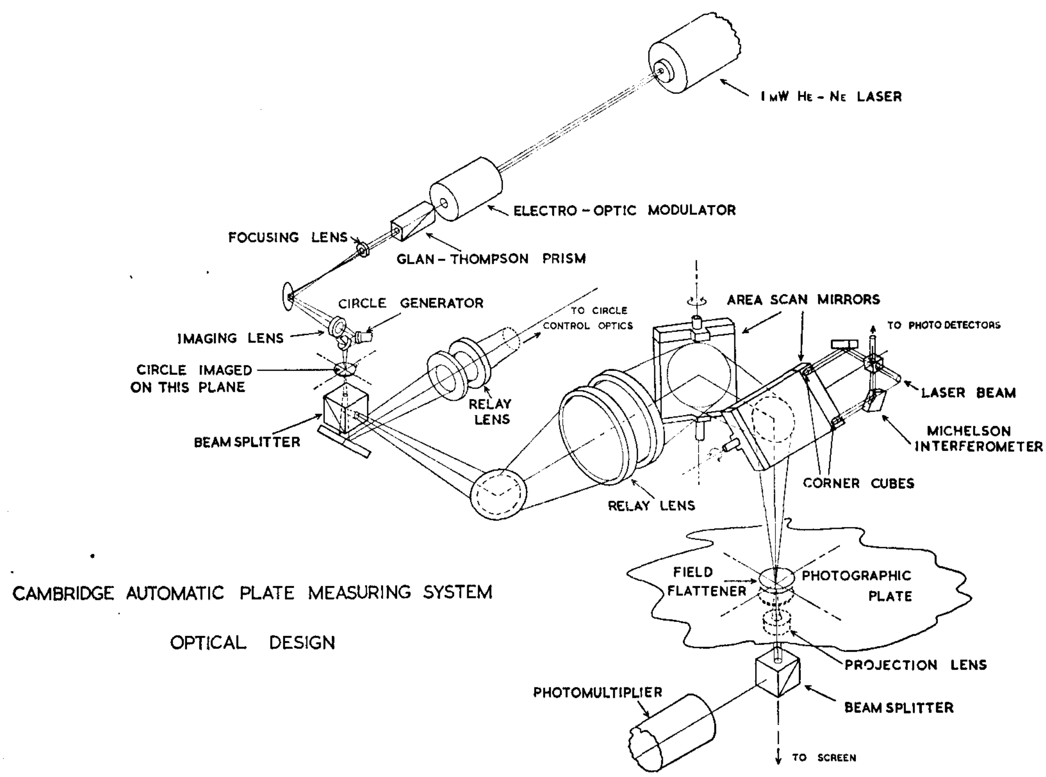

Fig. 1

focused laser beam is used as a flying spot to scan the image. The beam can be moved in a circle of variable radius or in a raster scan line of variable position angle at a frequency of 5 kHz and a response time of a few milliseconds. System hardware determines the coordinates of each image and these data, together with the image radial profile and harmonic components, are fed into the computer. Magnitude estimates and positional corrections will be obtained in the computer using image processing algorithms. The processed data will be stored on magnetic tape.

An outline drawing of the prototype system optics is shown in Figure 1. The laser beam is amplitude-stabilized by an electro-optic cell and is reflected off two small mirrors to form a focused spot imaged on a field lens. The beam is then split in half, one half feeding a system that stabilizes the radius of the circle and measures its diameter, and the other half being fed through a relay lens and reflected off two orthogonal mirrors before being focused onto the plate.

The mirrors can move the laser beam over about 1 cm^2 of plate with high speed and accuracy. The angular position of each mirror is digitized interferometrically to 0.6 arcsec (0.2 micron on the plate) with a computed response time of 20 milliseconds. The whole field is illuminated with filtered mercury light, to give a 25 × image projected onto a screen. The transmission of the plate is measured with a photomultiplier positioned behind a red filter which removes the mercury light.

The plate itself is carried on an X–Y table. When an area has been measured the table moves a new area under the mirror scanner. This table has only to be positioned to about 100 microns but its position must be known very accurately.

Originally the X–Y table was fitted with interferometers to measure its instantaneous position, but it is now proposed to use a system of fiducial marks. The photographic plate is to be clamped between glass plates so that a grid of fiducial marks (with accurately known positions) engraved on one of the surfaces is in contact with the emulsion. Alternatively, the marks can be exposed onto the emulsion as in the Carte du Ciel, which would perhaps allow film based emulsion to be used.

After the coordinate table has moved a new region under the area scanner, the four fiducial marks at the corners are picked up by the circle scan, and measurements of positions of images within the area referred to these marks. The area is then scanned in strips 1 mm wide × 1 cm long, using a raster scan generated from the circle using a fibre-optic circle-to-line converter. The image will be detected using software based on a program "Micscan" developed by Dr Jim Tucker at Cambridge for cervical smear screening. We have simulated this part of the system using a Vidicon connected to a PDP–7 computer and CRT display with extremely successful results. There is a very good data packing system and only 5k of store need be used for the second phase. Software thresholding is used and all stellar images can be detected even in steep background fog variations. The raster will digitise 1 cm^2 in 10 seconds and the software can analyse 500 stars/sec.

The positions and sizes of the images will be stored on disk in the final system, each new area overwriting the last area.

When this mode is complete the circle scan is moved by the mirrors to the approximate positions of each image in turn and the centres of circles and image brought into co-incidence using signals derived from the a.c. image transmission. The image is then sampled at set transmission levels to obtain its profile and Fourier harmonics of the scan frequency at this transmission level. These harmonics give the deviation of the image shape from a true circle and allow the computer to correct for small amounts of guiding errors and coma. The non-linearity of the photographic response sets fairly tight limits on how big a correction can be made.

More complex images such as those of galaxies or good objective prism spectra could probably be measured with the system by analysis of a raster scan of the image, despite the severe computational problems. The screen viewing is almost essential for this type of work since it allows the observer to interact with the system and assist the computer with more difficult pattern recognition problems.

A prototype system to test the design experimentally and to measure the performance of cruicial system elements is well advanced and should be finished in early 1971.

DISCUSSION

C. N. W. Reece: I should like to congratulate Mr Kibblewhite on this project; it is very exciting altogether. Some of the techniques proposed have been used by Professor Frisch at Cambridge on his machine that is being developed for digitizing hydrogen bubble-track pictures, so these are quite well proven. I think however that you may be underestimating the difficulties connected with the table.

E. J. Kibblewhite: I do not think the table is a difficulty, because the measurements are made with respect to fiducial marks for every new position of the table. When people accept fiducial marks they'll save £40 000.

J. Tinbergen: It strikes me that this is an extremely adult sort of marriage between computer techniques and mechanical techniques, a very good balancing of what the computer should and should not do.