LARGE SCALE PHOTOMETRIC SURVEYS USING ARCHIVAL PLATES

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ABSTRACT

Modern microdensitometers and image processing software suggest the possibility that it may soon be feasible to utilize the enormous amount of photometric and positional data potentially available on existing photographic plates. This paper describes the possibility of large-scale surveys and outlines a method for densitometric calibration of plates from an analysis of the detailed structure of the star images on the plate.

1. THE PROBLEM OF PHOTOGRAPHIC PHOTOMETRY

A photograph is an amazingly efficient medium for storing information. Each of the many thousands of star images on a plate can be located within a fraction of a millimeter and its brightness measured with a precision of a few hundredths of a magnitude. Often, however, only a tiny fraction of the stars are ever measured - it is simply too tedious to measure them all. Photography has, in fact, two major faults. Although information is stored efficiently, it is not easily retrievable (in a quantitative sense) and there is a non-linear relation between incident light and developed photographic density.

It now appears that the resolution of the first problem may be at hand. With computer-controlled microdensitometers such as the widely-used PDS machine, the density information on an entire plate can be digitized and stored on magnetic tape in a few hours. While this is still longer than it probably took to produce the photograph, it makes it possible to conceive, at least, of extracting all the information on substantial numbers of plates. In the immediate future a further improvement in speed of more than an order of magnitude seems possible using solid state array detectors to scan the plates. I have made a few tests with a scanning microdensitometer which uses a linear diode array as a detector. The array scans the scene in one direction and is stepped in the perpendicular direction to develop a

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raster scan of the entire photograph. With this particular device, it is possible to scan in excess of 10^4 pixels/sec, much faster than a PDS machine, with its single photomultiplier tube. The chief problem at the moment is scattered light and lack of dynamic range. The manufacturer of this particular device (Eikonix, Inc. of Bedford, Massachusetts) designed it primarily to scan objects in reflected light (such as maps, etc.) and so was not particularly concerned with either problem. Swaans (1979) considered the scattered light problem in a similar device and decided that it was solvable and the dynamic range can be incresed by better electronics, possibly combined with cooling the array.

Even a PDS machine generates numbers at a great rate,making the calibration and reduction problem acute. A number of people have developed methods for obtaining magnitudes from raster-scanned star images (see Hoag, 1978 for a review). Most of these procedures were developed with the idea in mind of being able to measure large numbers of stars more-or-less automatically. In all cases, however, it has been necessary either to use plates calibrated with sensitometer spots or to use a photoelectric calibration sequence covering the same range in magnitude as the unknown stars. Unfortunately, it is often the case that the plates extend several magnitudes fainter than available standards.

2. CALIBRATION BASED ON THE SHAPES OF STELLAR IMAGES

Is it possible to develop a procedure to use the information in the images of relatively bright, photoelectrically measured, star images to determine a densitometric calibration of a plate? From some preliminary studies I have been making, it appears that the answer to this question is yes, so long a certain conditions are met. It is necessary to assume, first of all, that the density in any point of an image depends only on the intensity of the light striking that point. It is necessary to neglect, therefore, various development effects or scattered light in the measuring optics. It is also necessary to assume that the distribution of intensity within a star image (the point spread function) is the same across the entire region to be measured. A plate with comatic images could not be used in this type of analysis. If these conditions are met, then there will be some function relating density and exposure:

$$D(x,y) = f\{E(x,y)\}. \qquad (1)$$

This is of course the characteristic curve. The exposure at some point in the image is given by a relation of the form:

$$E(x,y) = P(x,y)\cdot L_* + B \qquad (2)$$

where $P(x,y)$ is the point spread function, L_* is a measure of the brightness of the star and B is the background intensity.

For simplicity, I have assumed that P(x,y) is a gaussian of unit height. With this assumption, the width of the gaussian can be found by measuring the radius of the images of several standard stars at some arbitrary density. The quantity L_* is defined by the known magnitudes of the standards, and if the background level is uniform in the region of the standards, then B can be set equal to zero. Thus equation 2 can be used to determine point-by-point the value of E(x,y), which together with the corresponding values of D(x,y) lead to a solution of the characteristic curve (eqn. 1). When the images of the fainter stars are transformed into exposure, their magnitudes can be measured.

I have tested this procedure on a set of plates of the open cluster NGC 609, with satisfying results. The r.m.s. magnitude difference from plate to plate is about ±0.04 for stars brighter than about one magnitude above the plate limit. Since this field is one of many where the standards do not reach the photographic limit, it is not possible from this sample to say whether there may be systematic deviations in the magnitudes, but the good agreement between plates with different exposures looks promising. It will be necessary to try a field with a wide range of photoelectrically determined magnitudes to see how reliable the method will be. If the initial success is confirmed, then a large number of existing plates (particularly of star clusters can be re-measured to fainter limits and with many more stars.

REFERENCES

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