Advances in Densitometry

J. HAMBLETON

Joyce, Loebl & Co. Ltd.

Firstly I should like to apologise for Mr. Loebl's inability to come here today. Because of illness, he has been asked to rest and since he and I are working together on the same problems, he has asked me to present this paper.

It must be obvious to all concerned in the evaluation of photographic images, that microdensitometry has rapidly changed with the advance in technology. Improvements have taken place over the years in the use and refinement of double beam recording instruments. Present trends indicate that little further can be done regarding optical resolution and diffraction limited systems can now be built. The quantitative evaluation of images based on a line integral has not changed in principle for many years. A scanning spot of the requisite size is passed across, for example, a spectral line, and the densitometric profile line gives the information required, either by its height or its area.

Problems where the assumption of line integral cannot hold, present greater difficulties. Attempts were made to scan a number of densitometric tracings, then to evaluate the result, either by integration or other processes. This was essentially slow and the concept of flying spot instruments was introduced and a number of versions produced.

It is our considered opinion that the most important advances have been made in two-dimensional scannings and data processing, in fact the first leads to the requirement of the second. As already stated, the single dimensional scan is no longer acceptable to scientists and various forms of two-dimensional systems have been devised and these can be split into two basic types:

1. Digital.
2. Analogue.

The following digital systems have been designed:

1. *Slow Speed Flat Plate Scanners*
   Giving high resolution, good repeatability, at modest data rates. They can feed paper or magnetic tape recorders, or be connected on line with small digital computers. They do however, keep the facility to switch to graphical presentation by a simple adjustment, this facility being extremely useful and necessary to detect some of the spurious features described by Dr. Parrent. Such an instrument is in full production by my Company and a considerable number have been sold throughout the world. In fact, one of the first produced continues to give good service to the Royal Observatory here in Edinburgh.
2. *High Speed Plate Scanners*
   Such instruments are similar in principle to the slow speed scanner but allow data rates of up to 5000 measurements per sec. Because of the increased speed, great care is necessary in the design and construction of the optical system and table assembly. We have designed such an instrument, which also includes many other features not available in earlier instruments, spatial filters being one example.
3. *Drum Scanners*
   These are used where resolution is not so important but where increased speed is. Such a system can handle from 20 kHz to 50 kHz data rates and can feed directly a magnetic tape recorder or computer. Our drum scanners are used in many fields, ranging from air pollution to X-ray crystallographic analysis.
4. *Flying Spot Scanners*
   These instruments are extremely fast, but unfortunately are not Class 1 microdensitometers; they suffer from non-stationarity due to lens aberration and phosphor variation. This problem can be solved by using a computer and programming it to account for the errors. This can only be done however, if the sample consists of isolated spots such as X-ray precession spots and stars, etc. It is almost impossible to analyse continuous images. Arndt of the Medical Research Council[1] has developed an excellent F.S.S. instrument to analyse precession X-ray photographs.

https://doi.org/10.1017/S0252921100032413 Published online by Cambridge University Press

Another way of reducing the affect of non-stationarity is to restrict the raster scan and carry out a step/repeat operation over the sample. Such an approach is used on the Galaxy instrument.

For all of these instruments, the arrival of reasonably priced, fast data handling systems, such as magnetic tape recorders and computers, has changed the picture so much that speeds and accuracy can now be achieved which were impossible a year or two ago.

ANALOGUE SYSTEMS

1. *Plate Scanner*
   The analogue two-dimensional scanners take the form of equidensitometers, plotting equal density contours in black and white or in colour. One such instrument, designed by Technical Operations Inc., around the Joyce Loebl standard flat table microdensitometer, has the resolution, accuracy and other good features of the basic instrument. This instrument is known as the isodensitracer (IDT) and is designed so that the instrument can be easily utilized as either a standard recording instrument or an isodensity tracer. One such instrument was used by the American space authorities for mapping the moon; it was also successful in detecting the unmanned space probe, Ranger I, which crashed on the moon surface and had not been detected by any other means.
2. *Drum Scanner*
   The second form of equidensitometer uses the drum scanning principle. Such an instrument is manufactured by Technical Operations Inc., and is called the Image Quantizer. It is less precise but is extremely fast. It gives similar results to the IDT but has the added feature of plotting the derivative of the sample and this feature is extremely useful when analysing radiographs.

CONCLUDING

We consider all of the densitometers described will continue to play a major part in the analysis of photographic images. Most of the basic problems have been solved and only the application and the budget will determine the final speed and accuracy of future instruments.

REFERENCE

1. Arndt, U. W., Crowther, R. A. and Mallett, J. F. W., 1968. A Computer-linked cathode-ray tube microdensitometer for X-ray crystallography, *Journal of Scientific Instruments* (*Journal of Physics E*) Series 2, **1,** 510–516.

DISCUSSION

R. B. Dunn: In solar astronomy there is a great need for a microphotometer with the following characteristics: (i) two-slit optical system; (ii) 50 mm/sec speed; (iii) 25 μm steps; (iv) numerical tool control; (v) direct readout to computer; (vi) pin-registered film advance; (vii) enormously lower cost than the recent machines.

J. Hambleton: In reply, I would advise that one can have almost anything, but at a price.

(i) Regarding the two-slit system, this needs further discussion on the exact requirements.

(ii and iii) 50 mm/sec can now be achieved in 25 micron steps on our new fast densitometer.

(iv) This instrument basically has numerical tool control.

(v) This is also possible and computer controlled Joyce Loebl Microdensitometers are now being used in a number of countries.

(vi) I see no reason why pin-registered film advance cannot be provided.

(vii) Regarding price, our Autodensidater (automatically controlled Microdensitometer) is digitized and programmed to be moved in the x and y directions in 5 micron steps. This instrument can be interfaced with punch paper tape, magnetic tape or computer. The total cost of a recent computer system sold to Moscow University was in the region of £12 000. This instrument was designed to automatically analyse mass spectrum plates. When one considers what is being provided in such an instrument, I don't think the price is enormous.

K. Aa. Strand: Whenever a company has developed a good machine of some kind, which becomes an off-the-shelf item, then invariably, when the astronomer likes this equipment, he asks the manufacturer to make certain modifications, which for him are minor, but are major to the company making the instrument. Then these instruments become far more excessive in price than they really should be.

https://doi.org/10.1017/S0252921100032413 Published online by Cambridge University Press

For instance, in the case of the U.S. Naval Observatory, the two machines we have at our Flagstaff Station have been modified by Dr. Hewitt at a fairly reasonable price, so the data comes out in analogue form and also on tape which can be handled by a small computer.

W. C. LIVINGSTON: Dunn and Dennison designed a good microphotometer and then a commercial firm put it inside a Rolls-Royce box, you couldn't file it any more because it had this beautiful curved surface; a slight plea for an instrument which is angular and flat and you can put screwholes in!

J. HAMBLETON: First answering Dr. Strand, I would say it is inevitable that special requirements on standard machines must always result in increased costs. The extent of the cost depends upon the requirements. At the same time however, I am sure that the modification of a standard Joyce Microdensitometer would not cost the same amount as the instrument produced by your Flagstaff Station. Considerable funds have been provided in the past by research establishments to manufacture one-off densitometers, at an enormous cost. The establishment would have been much better off going to a manufacturer to do the job for him, mainly by modifying a standard instrument.

Answering Dr. Livingston, I would agree that too many manufacturers in the instrument field use sledgehammers to crack nuts. This is basically what he is implying when he talks about a Rolls-Royce box. I don't think this can be said about the Joyce Loebl Microdensitometer. Having sold almost 2000 of these instruments, it is obvious to me that the quality and price has been in the right region.

https://doi.org/10.1017/S0252921100032413 Published online by Cambridge University Press