Unsharp Masking

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ABSTRACT

A method has been developed using commonly available equipment and materials for extracting pictorial information from plates with ANSI diffuse densities approaching 5 while retaining detail down to the fog level of the plate. The technique, called unsharp masking, is a form of spatial frequency filtering that is particularly valuable with well-exposed Kodak spectroscopic plates, types IIIa-J and IIIa-F, but it can be used wherever image density is too high for conventional enlarging or copying methods. Full details of the necessary calibration procedures and examples of the resulting photographs are given.

INTRODUCTION

It is customary to process spectroscopic plates used for direct photography in a vigorous developer to optimize the detection of faint signals. The plates are contrasty and the brighter objects develop to very high densities. The apparent loss of detail in the denser parts of the plate is most pronounced with the more recent fine-grain, high-contrast Kodak emulsions, types IIIa-J and IIIa-F (formerly type 127). With these plates, densities well in excess of 4 (ANSI diffuse) can occur. This paper describes a masking technique that can be used to compress the tonal range of a plate without loss of fine detail in the image over a density range of 0 to 5.

Lutnes and Davidson (1966), Levy (1966), and Shepp and Kammerer (1970) described low-contrast developers that are claimed to give wide dynamic range without loss of detectivity. Latham (1974) suggests that development for low contrast is useful where plenty of light is available, but these modified development methods are not widely used and, it is common to take two or more separate plates to reveal, for example, the faint extensions of a galaxy and its brighter internal structure.

An important advantage of the technique described here is that it can be used with existing plates taken for other purposes. This is particularly relevant in the southern hemisphere, where often the only photographs of an object are deep Schmidt survey plates in which high density is combined with a need for enlargement. Enlarger exposure times become excessive at densities greater than 2, and microdensitometers cannot be used to explore the image at ANSI diffuse densities much above 3. Both microdensitometers and flying-spot electronic printers are expensive and limited to a relatively small scanning area. Unsharp positive masks, however, can be made for plates of any size up to the limit imposed by the contact printer, in this case 15 × 18 inches.

Photographic masking is a technique widely used in the graphic arts industry to control contrast in photomechanical reproduction. When printed in register with the negative from which it was made, a low-contrast positive increases the density in the thinner (shadow) parts of the image but leaves the highlights unchanged. The effective tonal range of the negative is thus reduced. If the mask is made slightly unsharp, registration of mask and negative is less critical and the mask acts only on the coarse detail of the subject. The mask thus acts as a low-spatial-frequency filter whose effect is to enhance rendition of fine detail while at the same time reducing gross density variations. The method has been investigated in some detail by Yule (1944).

In most previous reports on the use of unsharp masks, the diffusing effect was obtained either by printing through a diffusing screen or by means of spacers between the negative and the mask (Miller, 1976). The size and distance of the exposing light controlled the degree of unsharpness (Spiegler, and Juris,1931); Kodak, 1977). In the method reported here the thickness of the original plate acts as the spacer, and a diffuse-light contact printer is used to expose the mask. Special materials are not necessary with this technique, but a series of calibration curves is required to establish exposure and development times for the masks.

PRELIMINARIES

Contact printer

The relatively slow, fine-grained materials employed for copying make it essential that a diffuse-light printer with high maximum brightness be used in order to keep exposures reasonably short when exposing through densities greater than 4. The same printer should be capable of copying plates of low density with similar exposure times to avoid reciprocity effects in the copy film. The distant point tungsten source used by West (1974) for copying plates does not have the necessary brightness range, and it may distort the tonal scale of the copy if the grains of the original are well enough resolved to produce the "half-tone" effect (Altman and Peden, 1962; Clark and Nelson, 1962).

An Agfa-Gevaert model SV400 vacuum contact printer was used to expose both masks and copies. The platten of the printer is large enough to accept a full 14 × 14-inch plate, and its 20 separate tungsten filament sources ensure an even, diffuse light over this large area. The instrument was modified by incorporating a 12-position step switch to lower the brightness of the lamps by approximately equal values of log I from 1000 footcandles to about 0.1 footcandle measured on the glass platten.

Film and Developer

Kodak commercial film 4127 is a blue-sensitive, fine-grain film that has a long, reasonably straigh-line characteristic curve when it is developed in Kodak developer D-76 (diluted 1 part developer with 2 parts of water). The gamma can be varied between about 0.2 and 0.9 by changing the development time, and the D max is easy to control between 0.6 and 3.4 in the same way.

Calibration

The brightness steps of the printer were calibrated using the film/developer system described above. Development time was fixed at 5 minutes at 20°C. A 0 to 5 density step wedge was exposed on a single sheet of 4127 film at each of the fixed brightness steps of the printer to produce the series of curves shown in Figure 1. From these curves the exposure necessary to produce any chosen density up to 2 on 4127 film can be derived. These curves are particularly useful when copying both original plates and plates combined with masks to a standard sky background density irrespective of the sky/fog level of the original. The curves also indicate the relative brightness of the step-switch positions with respect to this particular blue-sensitive film.

Another series of curves is required to give values of D max and tonal range for different development times. In this case, the exposure remained constant and development was varied from 2 to 15 minutes, always at 20°C. The results are shown in Figure 2, together with a development-time/D max curve.

CHARACTERISTICS OF THE MASK

The purpose of masking is to reduce the wide density range of an original plate without reducing the density range of individual details. In this way small density differences at any point on the original's characteristic curve can be reproduced on a normal-contrast photographic paper. Prints can be made directly from the mask/plate composite, but it is much more convenient to use a film copy as an intermediate. The latter can be recopied to make a negative or enlarged or contact printed. The mask is exposed and processed in such a way that the density range of the original plate is reduced to about 1.5. This figure is not critical, and it depends to some extent on the anticipated use of the intermediate. However, processing the intermediate to a gamma of 0.55 ensures that this density range fits comfortably on the straight-line portion of one of the characteristic curves shown in Figure 1. Such an intermediate prints well on photographic paper of normal contrast.

The informational density range of the original, ΔD_O is given by

$$D_O \max - D_O \min = \Delta D_O,$$

where D_O min is the chemical fog plus the minimum sky fog level on the plate. Since the mask has little effect on images less than 2 mm in diameter, both D_O max and D_O min are measured with an aperture of 2 mm or larger.

If the mask is to reduce ΔD_O to a value of 1.5 when mask and original are combined, then the mask D max, D_m max, is given by

$$D_O \max - 1.5 = D_m \max.$$

For the mask to be effective over the total density range of the original, its D min should be at least 0.1 above fog.

As an example, consider a plate with a D max of 5 and a fog level of 0.2; i.e., the density range D_O is 4.8. In this unlikely event a mask with a D max of 3.3 would be required, corresponding to the curve given for 15 minutes development in Figure 2. The combined mask and plate would then have a D max of 5 + 0.1 and a D min of 3.3 + 0.2; i.e., the density range would be 1.6.

The family of time/gamma curves shown in Figure 2 is used for determining the exposure and characteristics of the mask. A suitable maximum mask density can be obtained for any combination of sky background and density range likely to be found on an original plate. The curves in Figure 1 are useful for making the intermediate masked copies at a gamma of 0.55. In most cases, a 10-second exposure is adequate for both mask and copy, but in the extreme example above a 30-second exposure at maximum printer brightness (step position 1) would be necessary to expose the intermediate copy correctly from the masked plate.

The flattening of the characteristic curves in Figure 2 as they approach D max is fortuitous. It enables a given D max to be obtained without critical timing and ensures that the mask is relatively ineffective at the low-density end of the original plate. Faint objects, irrespective of their size, are reproduced virtually unchanged in the final copy. The mask is therefore not linear. It exerts its maximum influence between densities 0.5 and 4 on high-contrast plates such as IIIa-J and IIIa-F.

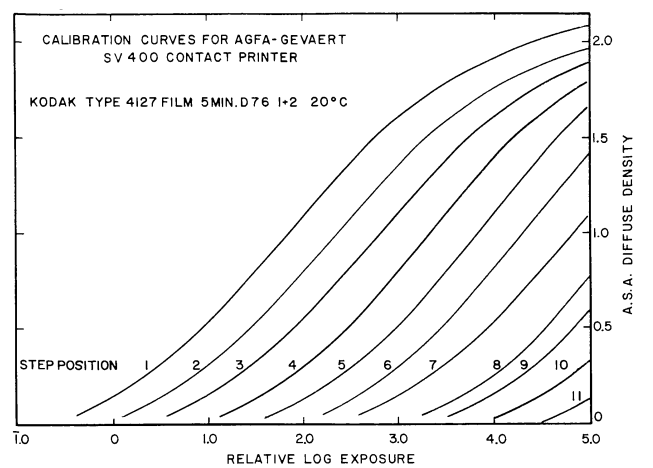

Figure 1. Calibration of brightness steps of Agfa-Gevaert contact printer.

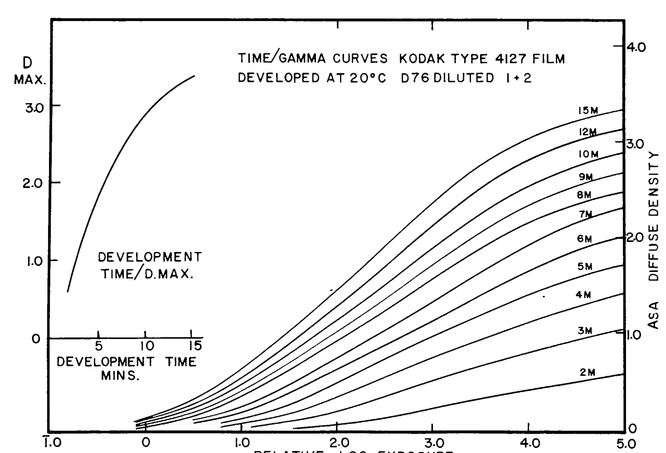

Figure 2. Time/gamma and development-time/D max curves for Kodak commercial film type 4127 in Kodak developer D-76, diluted 1 to 2.

If masks with linear characteristics over a wider range are required, the 4127 film can be processed in Ilford PQ universal developer, diluted 1 to 40. A 5-minute development produces a gamma of 0.55 over a log E range of at least 4. The film is much slower with this developer, but the system can be useful when it is necessary to alter relative densities equally at the extreme ends of the tonal range of an original plate. The 1 to 40 dilution is well outside the manufacturer's recommendation, and the developer should be mixed immediately before use and used once only. This system will probably reduce the resolution of the film both by edge effects from the dilute developer and by image spread from overexposure, but this does not affect its usefulness for making masks. A given D max can be obtained over a very wide range by altering exposure rather than development time.

Effect of plate thickness

Plate thickness will clearly affect the spatial frequency characteristics of the mask. This has not been explored quantitatively, but the maximum image size remaining unaffected by the mask changes from about 1 to 2 mm as the glass thickness is increased from 0.03 to 0.06 inch.

Making the mask and copy

After the density extremes of the original plate have been measured, the plate is placed emulsion down on the glass platten of the contact printer, and small opaque register marks are applied with a felt-tip pen. Both surfaces of the plate should be clean to avoid damage to the emulsion and pinholes in the mask. The plate should be completely free from residual antihalation backing. A sheet of film is placed emulsion down on the back of the plate and exposed through the glass of the plate.

The developed mask is held emulsion up on the printer platten, and the back of the plate is registered with it. The copy exposure is made through the mask with the copy material in contact with the plate emulsion. The required exposure, which is given by the mask D max plus plate D min, is obtained from the calibration curves shown in Figure 1. A D max of 1.2 to 1.4 is required on the copy at a gamma of 0.55. This value ensures that all the information from the composite falls on the straight-line portion of the characteristic curve of the copy material and that it is low enough on the curve to allow substantial enlargement in a condenser enlarger without excessive exposure times.

If masked copies are being made of portions of large plates, e.g., 8 × 10-inch sections of 14 × 14-inch plates, it is wise to ensure that the back of the plate is supported on scrap film of the same thickness as the mask to avoid breakage under the contact-printer vacuum.

RESULTS

Figure 3 (also the cover photo on this issue of the *AAS Photo-Bulletin*) is a positive print of the gaseous Carina Nebula (NGC 3372), derived from a limiting IIIa-J plate taken by the U.K. Schmidt Telescope Unit at Siding Spring, N.S.W. The D max of the plate was 4 in the region around the star Eta Carinae. The star itself can just be seen in the original, together with faint nebulosity extending to the edge of the print, just above sky background on the original plate. The edge effects produced by unsharp masking (Mees and James, 1966) emphasize the southern extensions. Note that stars in the line of sight can be seen superimposed on the brightest parts of the nebula.

Figures 4a and 4b show the spiral galaxy NGC 5236 (M83), photographed with the Anglo-Australian Telescope on a IIa-D plate with D max = 2.2. With care and patience it was possible to print this plate by hand-dodging in the enlarger. However, the mask emphasizes the dark lanes in the galaxy in a way not possible by any manual method. Note that very faint background galaxies are visible on both the masked and unmasked prints and that the dense images of bright stars are unaffected by the mask, being less than 2 mm across on the original plate before enlargement.

Figures 5a and 5b show the peculiar lenticular radio source NGC 1316 (Fornax A) as depicted by a deep 127-04 (IIIa-F) plate exposed with the Anglo-Australian Telescope. D max for this plate was 3.7. The masked version (b) reveals dark lanes in the center of the galaxy, and it clearly differentiates shells or steps in brightness out from the center that are not seen on shorter exposures and are hidden on the unmasked original. The morphology of this galaxy has been described by Burbidge *et al.* (1963) and by Arp (1964).

CONCLUSIONS

A method has been described for extracting information from well-exposed astronomical plates and presenting it in an easily accessible form. The unsharp masking technique is simple to apply and should be within the capabilities of any well-equipped photographic laboratory. It extends the usefulness

Figure 3. The nebula around Eta Carina. The print was made from a deep IIIa-J UKSTU survey plate via an unsharp mask.

a

b

Figure 4. NGC 5236 (M83). Prints made by enlargement (a) from an unmasked positive and (b) from a positive made through an unsharp mask from an original IIa-D plate.

a

b

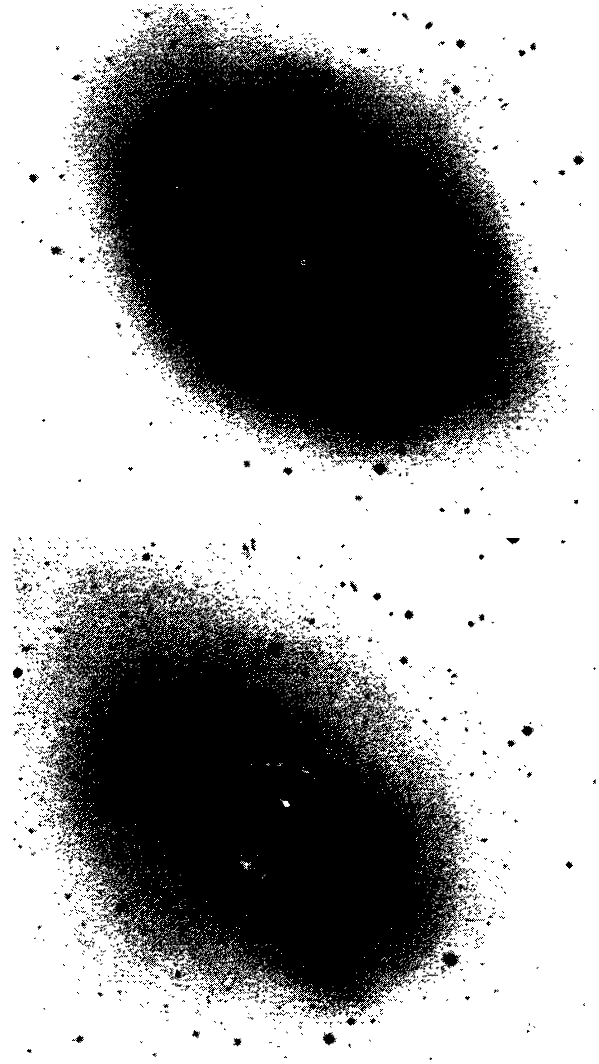

Figure 5. NGC 1316. Unmasked (a) and masked (b) derivatives from a deep 127-04 (IIIa-F) plate showing the central dust lane.

of existing plate archives and eliminates the need for multiple exposures of objects with a wide dynamic range. Unlike instrumental methods of contrast manipulation, very large plates can be handled quickly and without a restrictive upper density limit.

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