Removal of navigational lines from GMS images

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Until recently grid and coast lines were superimposed on GMS analogue images at Japanese command and data acquisition stations before being broadcast to ground receiving stations. These lines must be removed before any global image processing operations can be applied to such an image. A typical method of using a median filter for removing lines does not produce useable results since the rest of the image is degraded during the filtering process.
This paper describes a multi-stage method for line removal. An image is first preprocessed so that areas of high contrast are enhanced. A double adaptive thresholding technique is applied to locate pixels on lines. Line removal can be achieved by replacing each pixel on the lines by the average of pixels not on the lines in the local neighbourhood.

Introduction

The Japanese Geostationary Meteorological Satellite (GMS) program which started in 1977 uses the Visible and Infrared Spin-Scan Radiometer (VISSR) to generate full-earth disc images (Kingwell and Griersmith 1986, p. 16). There have been three satellites to date and the current satellite, GMS-3, was launched in 1984. An image is built up from a series of east-west scans which last about 25 minutes, coupled with a mirror which steps along the north-south axis once every satellite rotation. The signals are transmitted from GMS-3 to Japan where many computer processing tasks such as picture corrections, signal conversion, superimposition of grid and coast lines are done. The signals are then broadcasted via GMS-3 to reception stations. Recently the Bureau of Meteorology in Melbourne started to receive raw digital data directly from GMS-3 with the introduction of Stretched VISSR. However, images archived prior to 1989 contain superimposed grid and coast lines which need to be removed before any global image processing tasks can be undertaken.

Traditional methods for line removal such as median and band-pass filtering (Gonzalez and Wintz 1987, 161 ff.) use context free transformations of the entire image to suppress the local neighbourhood response typical of the lines being removed. Such methods are generally not acceptable for line removal when the image is to be subjected to further processing because every pixel would be changed leading to degrading of the whole image. It is therefore more desirable to locate pixels with high probability of being on a line and to apply a correction process to these pixels only. Usually this is a time-consuming task as a number of different conditions must be checked. However, if a simple transformation can be applied to the image to detect those pixels likely to be on the lines, the correction task becomes more manageable.

This paper describes a multi-stage method for removing grid and coast lines from GMS images. An image is first preprocessed so that areas of high contrast are enhanced, then a double adaptive thresholding technique is applied to the enhanced image to locate pixels on lines. A refinement step to locate line pixels with weaker response is also described. Once the lines are located, each pixel on a line is replaced by the average of background pixels in the local neighbourhood. The method has been applied successfully on (480 x 480) sample images extracted from a GMS image of the whole disc taken in May 1987.

Properties of superimposed lines

Grid and coast lines are superimposed on the digital data by changing pixel values at absolute positions in the navigated image space. A pixel value is changed to black if the value is white to mid-grey, or white if the value is black to mid-grey. In areas of mid-grey the lines will thus be less contrasting, but such areas are uncommon in a GMS image as the vast majority of pixels are either fairly bright (cloud) or fairly dark (sea and land).

The amended data with superimposed lines are transmitted in analogue form, scan line by scan line. Thus those parts of lines which are horizontal across the image will not be stretched vertically but may have some pixels of noise at either edge when the analogue conversion hardware detects a sudden change in response. In the case of vertical or near vertical lines, this effect is quite noticeable and lines are smeared out across several pixels, with a response similar to Figs 1(a) or (b), depending on whether the background is the same on both sides of the line or not. Where lines intersect or aliasing occurs, the region of smearing can be severe (cases with up to 8 pixels were observed in the chosen test image). Hysteresis effects in the analogue circuitry can cause the response to over-compensate for a few pixels causing a shadowing artifact as in Fig. 1(c).

Line removal method

The method consists of three stages: preprocessing, double adaptive thresholding and line removal. The diagram in Fig. 2 shows the

Fig. 1 Responses of superimposed lines.

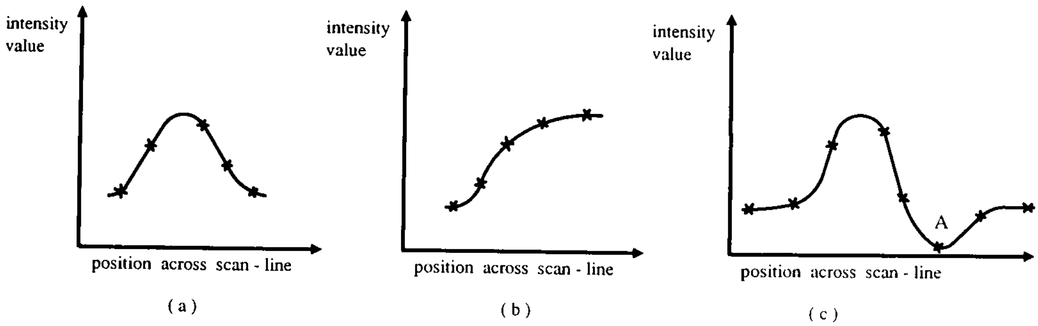
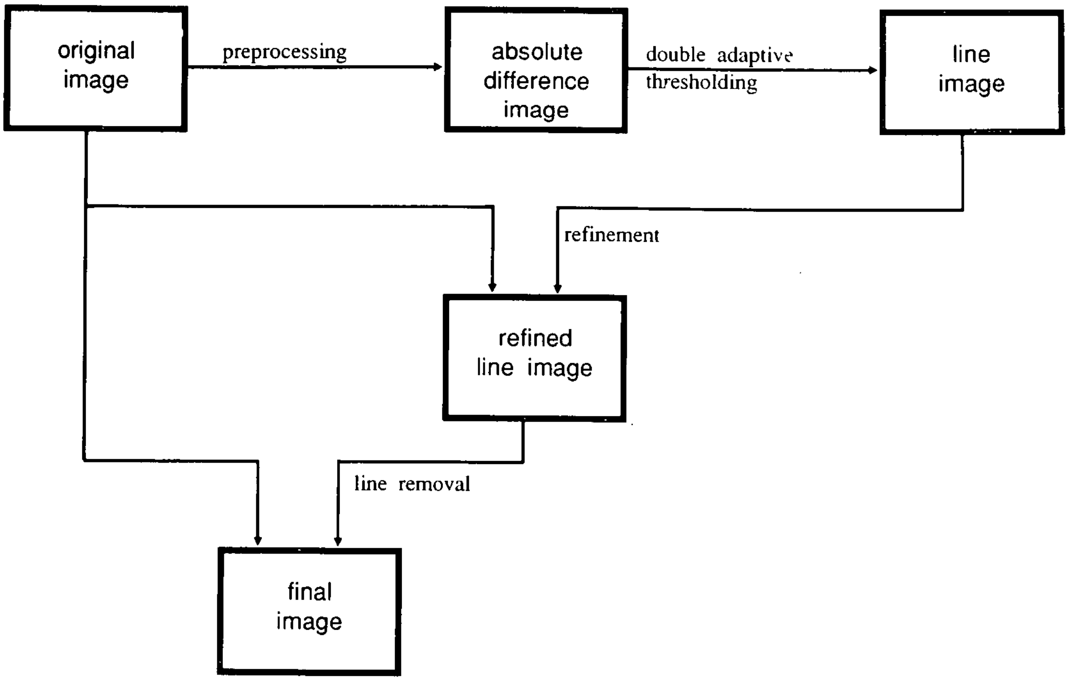


Fig. 2 Stages in line removal method.



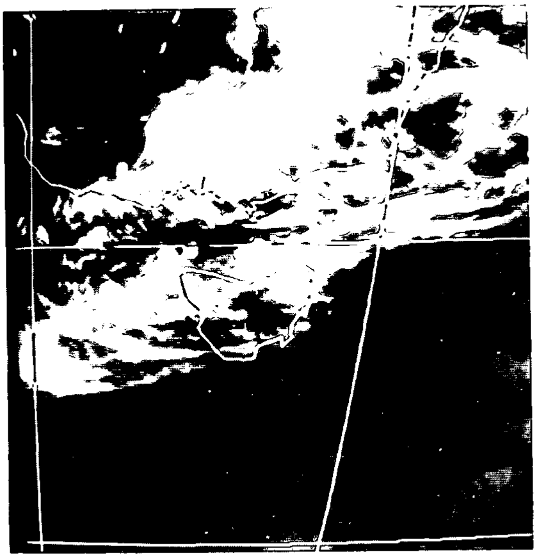
relationship between these different stages and the intermediate images formed during them.

An example of the original data is shown in Fig. 3(a) and the results obtained when applying the three stages are shown in Figs 3(b), (c) and (d).

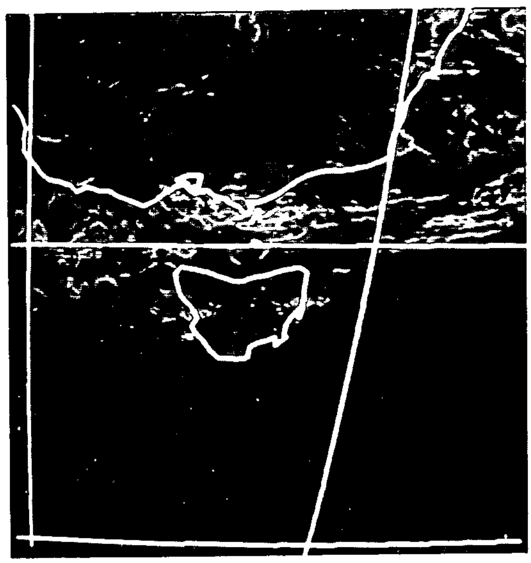
Preprocessing

Thresholding techniques can only be used successfully for extracting lines from an image if the contrast between lines and the background is significant. Furthermore, the intensity of line pixels should not vary too much. Both lines and background in a GMS image have a large range of intensity from black to white (see Fig. 3(a)). We therefore need to preprocess the image so that the contrast between lines and background is more enhanced, at the same time reducing the variability of the intensity within lines and within different regions in the background. These effects are achieved by using a local non-directional transformation (Gonzalez and Wintz 1987;

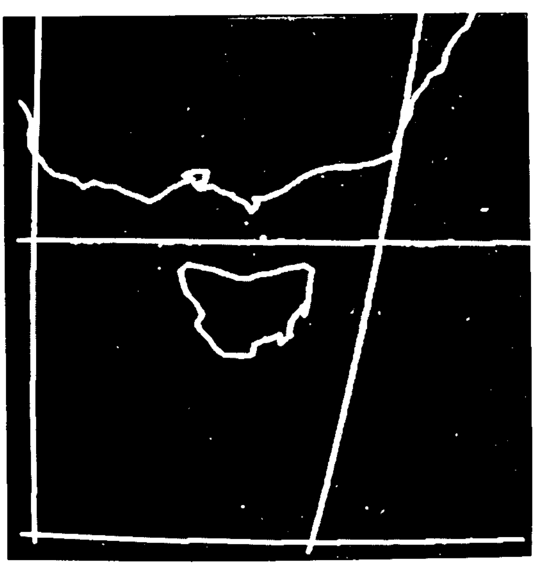
Fig. 3 Images used during the line removal process.



(a) Original image



(b) Absolute difference image



(c) Refined line image

(d) Final image

158 ff.) which replaces each pixel by the sum of its absolute differences from the eight neighbours. As the differences within a region have low values, areas of white clouds which would have caused a problem in thresholding earlier have now turned into much darker areas (see (Fig. 3(b)). The intensity of line pixels across any scan-line follows the response pattern in Figs 1(a), (b), or (c) as a result of the form of analogue signals. Hence, line pixels have high difference values and lines become more uniformly white after the preprocessing. The image in Fig. 3(b) is much more suitable for thresholding than the original image in Fig. 3(a).

Double adaptive thresholding

Although the absolute difference image is an improvement over the original one for our purpose, there is still a large variation in the intensity of the background. Furthermore, the intensities of some background pixels differ from those of line pixels by only small amounts. Hence a simple thresholding technique using one single cut-off value would not be appropriate for extracting the lines. We use instead a double adaptive threshold, based on an optimal thresholding approach (Gonzalez and Wintz 1987, 354 ff.). This technique has been successfully used for extracting lines from grey scale images of industrial drawings (Watson et al. 1984).

Double adaptive thresholding requires two threshold values to be used. The low threshold is a fixed global value below which all pixels can be ignored as they are too dark to lie on a line. The high threshold is a local value which is recalculated for each window of predetermined size over the whole image. The formula used for this calculation must be chosen to distinguish line pixels based only on pixels brightness properties within the window. Once the high threshold has been calculated for a given window, all pixels above the low threshold within that window can be classified as line or background pixels.

The low threshold used for ignoring definite background pixels can be detemined from the intensity histogram of the absolute difference image. The first significant valley in the histogram would be the ideal value for the lower threshold. For each pixel with intensity value greater than the lower threshold, the local upper threshold is calculated as the average of neighbouring pixels within a window of chosen size. Only pixels of value greater than the lower threshold are used in the average calculation.

The size of the window depends on the thickness of the lines to be removed. In the GMS image used, lines have maximum width of 5 pixels, hence a window of size (7 x 7) is sufficiently large to take into account the background information. A cut-off factor may also be used for weighting the average. This factor depends on how bright the line pixels are relative to the bright regions of the background in the absolute difference image. Well-distinguished line pixels can be found using a cut-off factor close to 1, whereas those which are of similar brightness to the background require a lower cut-off factor. For our GMS test image, we used 0.8 as the cut-off factor. The window average is multiplied by this factor before pixel values are tested against it. Pixels which exceed both thresholds are labelled as tentative line pixels for later use.

Although this procedure would locate most pixels on the line, it fails to extract those of low value if the intensity of line pixels across a scan-line follow the pattern in Fig. 1(c) (for example, pixel marked A). This is due to the fact that many of its neighbouring pixels are of higher value than itself. To locate such pixels, we need to do an extra refinement step by examining the 8 neighbours of each labelled tentative line pixel. For each of these neighbouring pixels, we calculate a local upper threshold using the local neighbourhood average formula as before. Only pixels which exceed the lower threshold and were not previously labelled as tentative line pixels are used in calculating the local average. Pixels which are classified as line pixels by exceeding this new local upper threshold in the refinement step are finally labelled as line pixels.

The double adaptive thresholding stage will give us an image which shows the location of lines to be extracted (see Fig. 3(c)). This image, where line pixels are displayed as white on black background, will be used as a mask at the final stage for removing lines from the original image.

Line removal

Both the original image and line image are scanned simultaneously to track the line pixels. In the original image, each pixel which corresponds to a labelled line pixel in the line image, is replaced by the average of the background pixels within a window of a fixed size. The window is again chosen sufficiently large to extract enough information from the surrounding background intensity since line pixels are not used in the average calculation. The rest of the image will be left unchanged. A (7 x 7) window is used for averaging in our test image. Figure 3(d) displays a final image where all lines are removed.

Conclusion

The method described here has produced similar results when applied to several other (480 x 480) images extracted from different areas in the same

GMS image. These final images were used as data for an automated cloud classification project in which the original images produced unacceptable classifications due to the bias introduced by the line pixel values. The method has also been used for other purposes such as recognising lines in digitised grey scale maps and drawings (Pham and Maeder 1989). This demonstrates that the method described is quite robust as well as being effective for the task of removing grid and coast lines from GMS images.

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