Image Coding Based On Contour Models

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Abstract

This paper investigates the use of iso-intensity contours for image coding. It is shown that compression ratios comparable to existing techniques may be achieved and that in addition to this the contours may be used to carry out vision operations such as object recognition and stereo matching directly from the compressed form of the image.

1 Background

The advent of the Integrated Services Digital Network (ISDN) has resulted in a resurgence of research activity in the field of image coding. The target is to transmit real time image sequences over a number (< 30) of parallel 64kbit/s channels in order to implement fast document transfer, video telephone facilities and eventually video teleconferencing. Digital images typically occupy a large amount of memory. To transmit an uncompressed sequence of images would require enormous bit rates of the order of 2^{26} bit/s. The need for efficient image coding strategies cannot therefore be overstated. Existing image coding techniques exploit the mathematical redundancies in the data set. They treat the image simply as a set of numbers making no use of image analysis techniques. Subsequently their error measures are more concerned with mathematical differences than perceptual significance.

The research areas of image coding and image analysis have been pursued almost independently with very little interaction. It is a widely held belief [1] that the two communities must come together if a genuine "quantum leap" in compression rates is to be achieved. Images must be coded in terms of their scene content. This paper describes an image coding scheme based on image contour models. It extends earlier work in this area which includes Wilkins [2] and more recently Marshall [3].

1.1 Model Based Image Coding

Ultimately it is expected that images and image sequences will be coded in terms of three dimensional models of objects contained in the scene. This will lead to very high compression ratios as only a small number of motion vectors will be transmitted to code the motion from frame to frame. The task of fitting three dimensional models to images in real time is, however, still well beyond current capabilities and is likely to remain so for some time to come.

The models used in this paper are two dimensional planar contours of constant intensity. These represent an intermediate stage on the way to 3D model based coding. The value of contours for representing two dimensional functions is clearly demonstrated in the field of cartography. Consider a relief map of a landscape. A set of smooth, sparse, closed curves connecting points of uniform height conveys a very accurate impression of the underlying landscape. A digital image may be coded in an equivalent way by re-

BMVC 1991 doi:10.5244/C.5.43

cording points of constant intensity. Intuitively contours represent a type of "self tuning sampling", that is they are distributed closely in areas of rapid change in intensity, where they are required, and are sparsely distributed in areas of near constant grey level value.

2 Coding Results

A set of test images were contoured at a number of levels using a contour tracing algorithm. Previous research [3] has shown that fifteen levels carefully allocated is usually sufficient to represent an 8 bit image. Figure 1 shows an original test image and Figure 2 shows the contoured version of the image. It was possible to retain only the contour segments and then to reconstruct the image using a zero order hold interpolation method. The reconstructed image is shown in Figure 3. The contour segments may be coded using two main methods.

Figure 1
Original image

Figure 2
Contoured image

2.1 Freeman chain coding

Freeman chain coding [4] is the simplest and most efficient coding scheme. Each contour segment requires a starting code plus 3 bits per element to indicate which of the eight possible directions the curve takes on a rectangular grid. It was found that relative chain code was more effective than the absolute code. The relative code (i.e. change of direction) had a much less uniform distribution than the absolute code and hence predictive or Huffman coding [5] could be used to realise an overall reduction in the total data stored. A disadvantage of Freeman chain code is that it is not particularly effective as a shape descriptor following changes in scale or rotation of the contour. It is also inefficient for short contours. It was found that short contour segments of less than 5 pixels in length could be deleted with no noticeable change in image quality.

Relative chain code may be considered as a first order prediction process. This process may be extended to higher orders of prediction in which blocks of codes are represented by a single overall code. Clearly certain combinations of codes will be much more likely to occur than others and hence predictive coding may be used to reduce the overall data rate. This method has the disadvantage that for data blocks larger than 5 elements the resultant memory requirements make the method impractical. When the contours of the image were retained in this way using 8 way chain code with 5 element predictive coding the total data requirement was 6416 bytes compared to 64kbytes for the original image, yielding a compression ratio of 9.79%.

2.2 Hybrid Fourier/Freeman Coding

Contours may be coded by shape descriptors such as Fourier shape descriptors [6]. This has the advantage that a particular shape may be identified in an image regardless of its scale, translation or rotation directly from its compressed code. The number of coefficients required means that this method is only effective for longer contour lengths. Depending on the number of coefficients retained the contour may not be capable of representing sharp corners. In the implementation used the description was normalised and then factorised into components which represented purely shape information and those which indicated scale, rotation and positional information. The shape descriptors were stored as a codebook of commonly occurring shapes which were scaled and rotated to fit the image contours. When the longer contours were coded using Fourier descriptors and the shorter ones using Freeman chain code, the total compression ratio was reduced to 8.7%. The resulting image is shown in Figure 4, notice that some of the sharp corners have been smoothed.

Figure 3
Reconstructed Image

Figure 4
Fourier coded image

3 Vision operations using contour models

As well as being an effective coding model image contours have the advantage that they frequently correspond to object boundaries within images. It is therefore possible to carry out object recognition and stereo matching directly from the compressed representation. Where Fourier coding techniques have been employed shape and object recognition may take place regardless of scale, rotation and translation of the shape. When the image in Figure 5 was contoured and then converted to normalised Fourier coefficients, it was possible to identify the contours corresponding to the object boundaries regardless of their scale, orientation or position. The boundaries of the objects identified by this method are shown in Figure 6.

Similarly a stereo pair of images were contoured and corresponding contours were sought from each image. Those contours with similar shape, scale and orientation and meeting disparity and epipolar constraints were identified as corresponding to stereopairs and are shown in Figures 7(a and b).

Figure 5
Objects on a desk

Figure 6
Recognition of objects

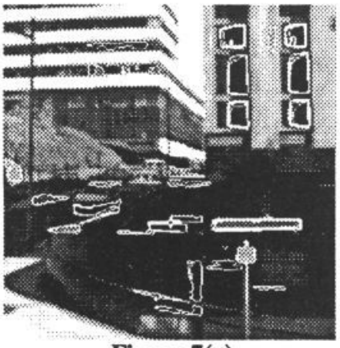

Figure 7(a)
Left stereo image

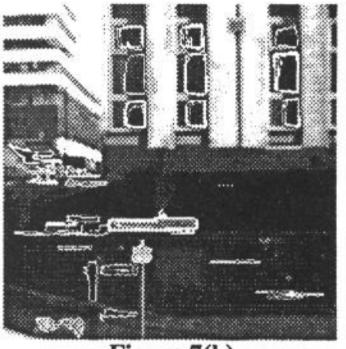

Figure 7(b)
Right stereo image

4 Conclusions

This paper has demonstrated the use of contours of constant intensity as a model for image coding. Compression ratios have been achieved which are comparable to existing classical methods. These methods have the advantage, however, that higher level vision operations such as object recognition and stereo matching may be carried out directly on the compressed form of the image.

5 References

[1] Kunt, M., Ikonomopoulos, A., Kocher, M., Proc IEEE, 73, 1985, 549-574.

[2] Wilkins, L., C., Wintz, P., A., "Studies on Data Compression, Part 1: Picture Coding by Contours", TR-EE 70-17, School of Electrical Engineering, Purdue University, Lafayette, Indiana, 1970.

[3] Marshall, S., "Application of Image Contours to three aspects of Image Processing: Compression, Shape Recognition and Stereopsis", PhD thesis, University of Strathclyde, UK, 1989.

[4] Freeman, H., "On the Encoding of Arbitrary Geometric Configurations", IRE Trans. Electronic Computers, 1961, 260-268.

[5] Jayant, N. S., Noll, P., "Digital Coding of Waveforms", Prentice Hall Inc., 1984.

[6] Zahn, C.T., Roskies, S., "Fourier descriptors for plane closed curves", IEEE Transactions on Computing, Vol C- 21, 1972, 269-281.