Segmentation Using Region Merging with Edges

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This paper considers a hybrid segmentation technique which uses an iterative merging algorithm. Both region and edge based data are used to guide the merging process. The inclusion of edge data provides two significant advantages — enhanced segmentations and a closer link between the edges and resultant region boundaries.

1 INTRODUCTION

Segmentation is the division of an image into a number of contained self-consistent regions. Each region must be homogeneous with respect to a particular property – such as intensity, colour or texture. Ideally the regions will clearly relate to distinct elements or objects within the scene. In general segmentation can be achieved by one of two approaches — either using a region based method which forms regions by considering their overall properties, or by using an edge linking approach which looks for rapid luminance changes signifying regions boundaries.

Many different region methods have been investigated. These include for example, split and merge pyramid techniques [e.g. Pietikainen et al (1982)] and histogram directed clustering [e.g. Ohlander et al (1978)]. Region growing methods can work well if the various components within an image are in good contrast against each other. Problems arise though in areas of gradual grey level variation where the region boundaries become less distinct. This leads to a leakage phenomenon in which neigbouring areas become merged even though a strong edge may exist along some of the common boundary.

An edge detection approach is much more sensitive to this type of situation, but here the problems are different. Edges of varying strengths are located and these must not only be linked together into strings, but the edge strings themselves must be joined to form closed regions. The problem of closure is not straightforward to solve. Many edges may terminate in the same vicinity or there may be large gaps to be bridged. Furthermore, only the edge data within an image is being utilised while the large bulk of internal area based information is being ignored.

Consequently it seemed desirable to evolve a hybrid region based segmentation algorithm that would inherently take into account edge based information. A region merging technique was therefore developed that could easily be adapted to utilise edge data. The merging algorithms took the individual pixels as a starting point and then iteratively and systematically connected them to form large regions. In fact a two stage process was devised involving a pre-segmentation algorithm — COALESCE, followed by a more rigorous algorithm — FORCE. To use edge data a digitisation algorithm was developed. The segmentation processes and the incorporation of this digitised data are described in section 2. Segmentations without edge data are also presented, while the results of utilising edge information and the digitisation method itself are left until section 3.

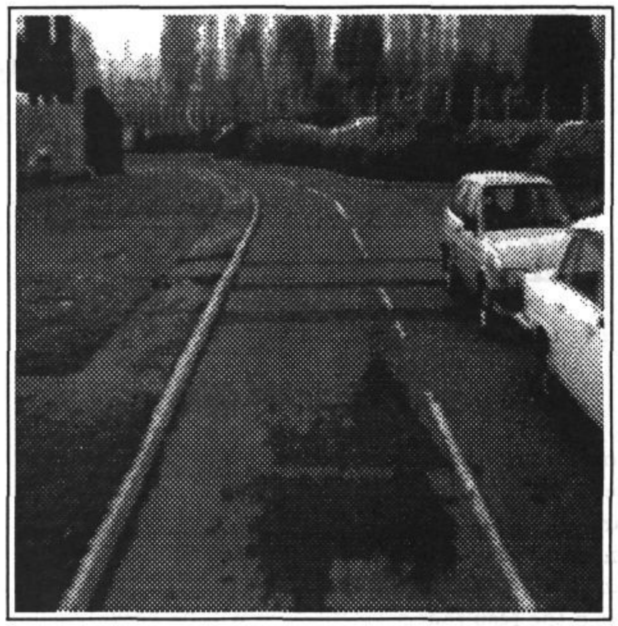

Figure 1 : Raw Grey Level Image

2 ITERATIVE REGION MERGING

Pre-segmentation (Stage 1)

In order to use edge data, the segmentation method was based purely on region merging. Region splitting was rejected as this approach reproduces many of the difficulties of edge linking and closure. It was also decided to avoid, as much as possible, putting any structural bias in the algorithm. Pyramid structures for example impose a fixed lattice structure from the higher pyramid levels and this often leads to a 'blocky' tendency in the resultant segmentations.

Region merging involves identifying each pixel in a raw image as a small region and then merging regions

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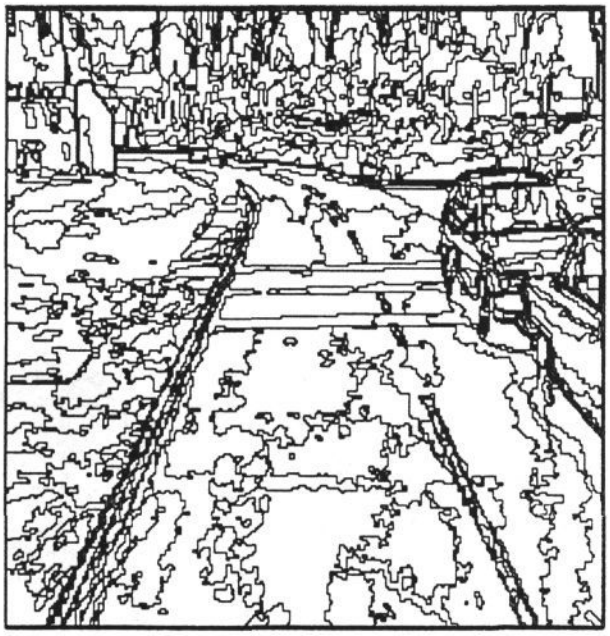

Figure 2 : Pre-Segmentation (COALESCE) with NO Edge Data

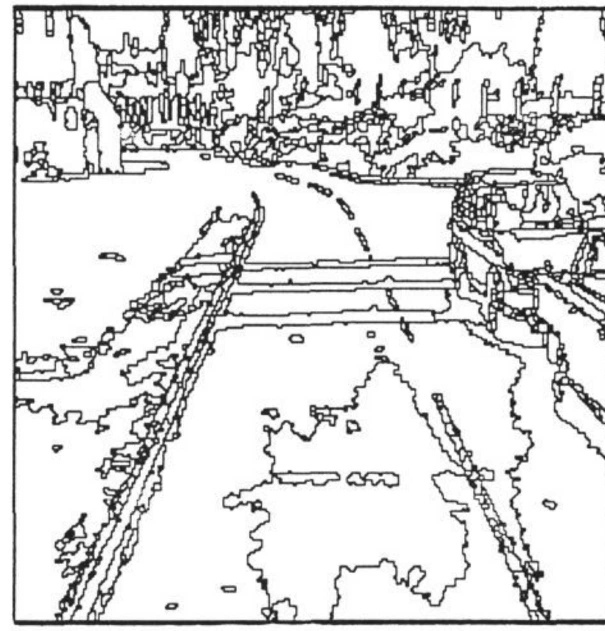

Figure 3 : Final Segmentation with NO Edge Data

together systematically to grow larger regions. The criteria for deciding whether or not to merge two regions are central, but equally important is choosing the order in which to examine the region pairs. Merging can start at nucleation centres, but if this proceeds too 'quickly' then the resultant segmentation will be very dependent on the initial selection and location of these centres. Consequently it is important for merging to take place 'gradually' over the image as a whole. It is with this in mind that the COALESCE segmentation module was developed.

The algorithm can be summarised as follows —

1. A maximum allowed grey level range within each region (G) is defined globally and initially set to zero. (This connects neighbouring pixels together of the same grey level).
2. G is then increased by one unit and any clusters of regions satisfying this new constraint are merged.
3. The whole region map is updated accordingly before G is increased again in the next iteration.
4. The process repeats (from stage 2) until a preset maximum is reached.

Full details of the algorithm are given by Page (1988). There are two further points to note —

- On a given iteration each region is considered in turn and its grey level range extended up by one unit or down by one unit. Both alternatives are examined to choose which gives the more homogeneous result in terms of merging with neighbours.
- Knock-on effects are taken into account, i.e. if region B can merge with region A (the main region under consideration), then region B's neighbours are also tested to see if they fall within the local range limits of A.

A typical image and its resultant segmentation (without using edge data) are shown in Figures 1 & 2 respectively. A maximum range of G = 35 grey levels was used. At this stage no segmentation errors have been produced, but there are far too many regions.

Edge data can be utilised by preventing merger between adjacent regions if the edge strength along the common border is greater than a set threshold. A record of the average edge strength between each pair of regions is maintained and updated when appropriate. Such edge data can be supplied separately from an external edge detection algorithm, but the edges need to be digitised first into a convenient form to be compatible with the pixelised nature of the raw image. Details of this process are outlined in section 3.

Segmentation (Stage 2)

The COALESCE algorithm is good at providing an initial segmentation, but produces poorer results if too many iterations are allowed. Consequently a second and more rigorous merging algorithm FORCE was developed. FORCE maintains a list of all adjacent region pairs and calculates the merging force between them. The merging force has two components — an attractive term, based on the similarity of the grey level means of the two regions, and a repulsive term originating from the strength of edges on the common boundary between them. The whole image can be thought of as being in tension. The algorithm proceeds as follows —

1. The force between all adjacent region pairs is calculated. (The repulsive term is included if edge data is used.)

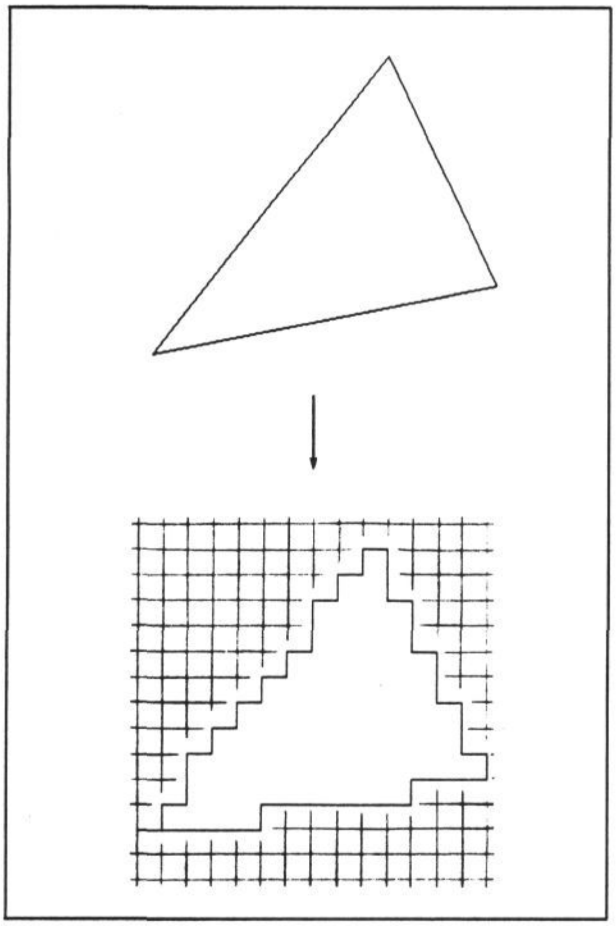

Figure 4(a) : Digitisation of a Triangle

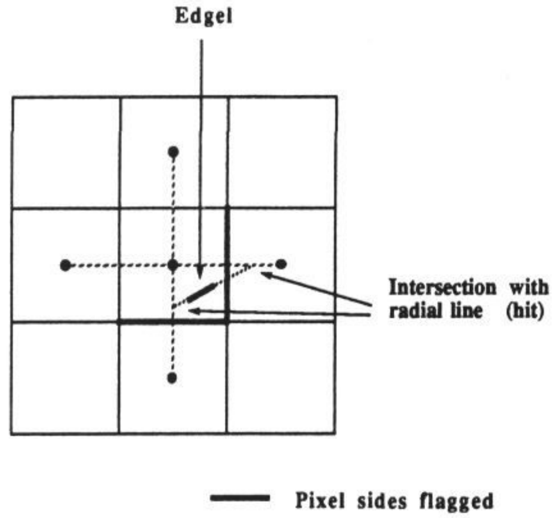

Figure 4(b) : Digitisation of an Edgel

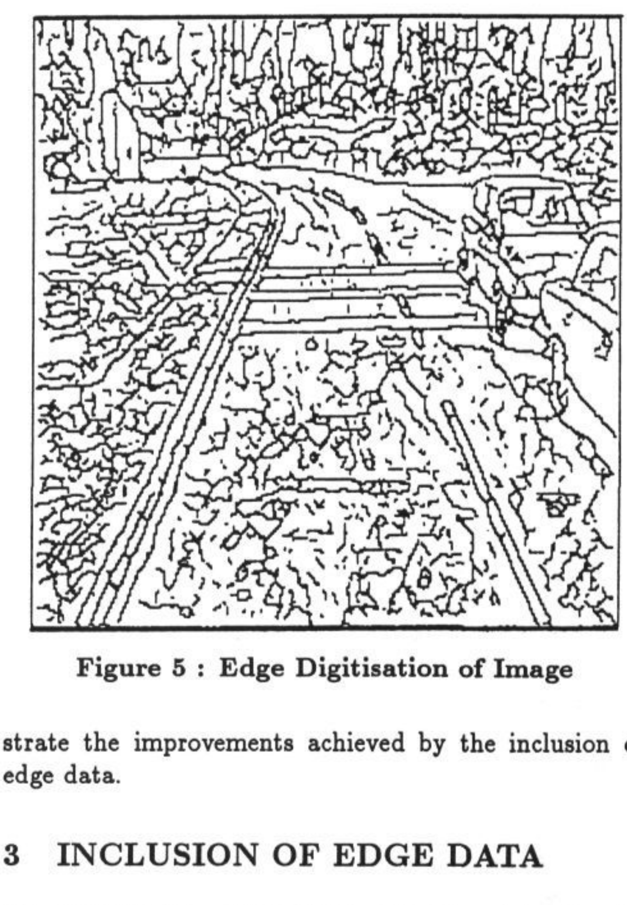

Figure 5 : Edge Digitisation of Image

2. The two regions with the greatest overall attractive force are merged.
3. The forces in the local vicinity of the merger are updated.
4. The process repeats (from stage 2) and merging continues until a preset threshold is reached indicating that all the forces within the image are sufficiently low.

As FORCE only reduces the number of regions one at a time, COALESCE is used as a pre-segmenter, before letting FORCE take over. The results of this combination* (without using edge data) are shown in Figure 3. Many of the road features are well defined, but problems have occurred near the top where the road has merged with the pavement and grass area. The cars and shadows are distinct, but in general there are too many insignificant regions. Increasing COALESCE and FORCE thresholds alone does not seem to solve the problem. However as will be demonstrated, the use of edge data does significantly improve the segmentation.

It should be noted that a number of similar images have been processed by this method and subjectively the results varied from fair to quite good. Figure 1 gave one of the least good results and so has been chosen to demonstrate the improvements achieved by the inclusion of edge data.

3 INCLUSION OF EDGE DATA

Generally it is not possible to use edge data directly in segmentation processes because segmentation is pixel based whereas edge detectors usually produce data in Cartesian form (often with sub-pixel accuracy). The Canny operator [Canny (1986)] and British Aerospace VISIVE edge detector [Overington et al (1987)] fall into this category. For this paper the latter has been used. If an edge exists in the form of a line then it needs to be digitised to create a staircase pattern in which the elements of the staircase are aligned on the pixel boundaries (See Figure 4(a)).

Ideally the edges would be supplied as a series of linked points from which the appropriate staircase pattern

*Additional programs SINUOUS and SMALL have also been used as a final stage to remove residual small regions [Page (1988)].

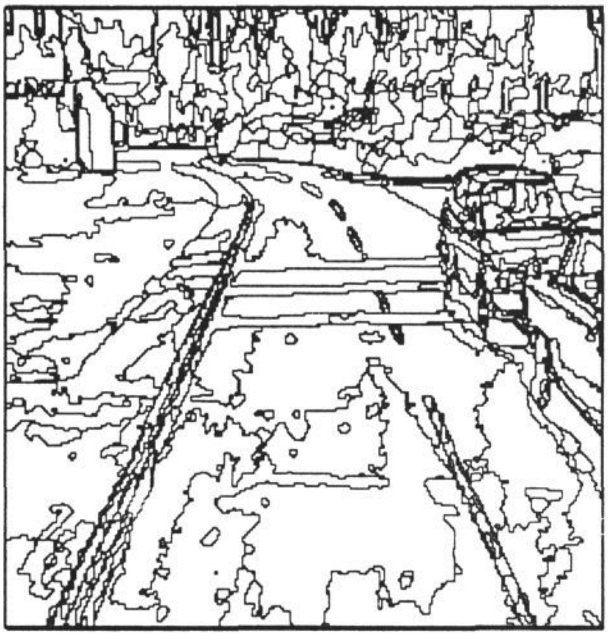

Figure 6 : Pre-Segmentation (COALESCE) with Edge Data

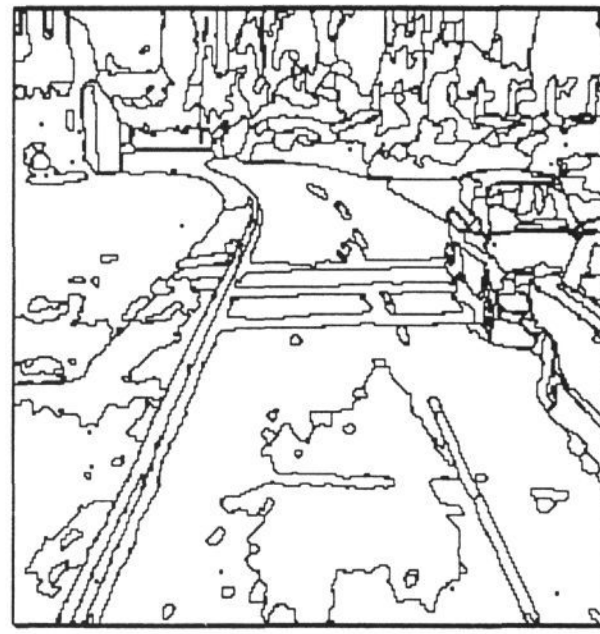

Figure 7 : Final Segmentation with Edge Data

could be uniquely derived. However, the linking of edge points requires some higher level processing involving bridging points and the resolution of multiple intersections. Such higher level processing can lead to errors and is not necessary since segmentation will resolve many such ambiguities automatically through its merging and region growing processes. It was therefore felt to be better to use unlinked edge data. The edges are supplied as individual points in terms of location, edge strength and edge orientation.

The method of digitisation is most easily illustrated by reference to Figure 4(b). Consider an edgel in the central pixel, also noting the radial lines joining the central pixel to its four neighbours. The edgel is projected so that it hits these radial lines. Pixel sides perpendicular to these lines are then flagged as being part of the digitised edge. Either one or two sides are flagged each time. (If an edgel intersects a radial line at $< 5°$, the hit is disregarded thus minimising spurious hits due to noise when the edgel is near the vertical or horizontal.) Figure 5 shows a digitised edge map. The staircase patterns lie between the pixels making it now easy for the corresponding edge strengths to be used to guide the segmentations. Figure 6 shows a COALESCE segmentation using this data in which G_{max} has been allowed to increase to 50 grey levels. For this reason there are fewer regions compared with Figure 2. The presence of the edge data has increased stability and avoided leakage. Consequently it may be all right to allow the pre-segmentation stage to do more processing and so reduce the load on FORCE. This though needs to be examined further.

Figure 7 shows a segmentation using COALESCE (to $G_{max} = 15$) and then FORCE. The digitised edge data has been utilised within the repulsive term of FORCE. It is important to note that both segmentation algorithms use the edge strength integrated over shared boundaries between regions. Consequently missing or weak fragments in an edge line do not give rise to the leakage problems (mentioned earlier). The Figure 7 segmentation is significantly better than that of Figure 3 in which edge data was not used. There are fewer small fragmented regions and the road boundaries are better defined. In particular the road, pavement and grass have been kept separate. It is worth noting the following points —

- Although most of the time the digitised edges are not continuously linked, the segmentation processes in utilising both region and edge data, effectively perform the linking. This is demonstrated in Figures 3,5 & 7 by the closurer at the road junction.
- Edges do not necessarily give rise to regions — only if they are reinforced by other edges and region data.
- The region boundaries can now be identified with elements in the digitised edge map which can in turn be linked back to the original edge data.

4 CONCLUSIONS

Using digitised edge data in a hybrid region merging algorithm has been found to produce good segmentation results. The use of region based data in conjunction with edge data enhances the region merging process and increases stability. The region maps and original edge data can then easily be realated to each other. This work has currently been applied to a limited set of images which in future need to be extended.

5 Acknowledgements

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6 REFERENCES

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