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VERSATILE AND EFFICIENT HIERARCHICAL CLUSTERING FOR PICTURE SEGMENTATION

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Abstract: An efficient implementation of a segmentation algorithm based upon hierarchical clustering is presented. The algorithm starts with an initial picture partition, and at each iteration, the two most similar segments are merged by optimizing a "step-wise criterion". This yields a hierarchical decomposition of the picture. The implementation avoids recalculation by updating the only values that are modified by a segment merger. Moreover, data structures are employed to organize image data and to reduce computing time. The versatility of the algorithm is illustrated by the combination of a constant value approximation criterion with two segment shape criteria.

HIERARCHICAL SEGMENTATION

In hierarchical clustering, the number of clusters is sequentially reduced by merging. At each iteration, the similarity measures $C_{i,j}$ are calculated for all clusters pairs, and the clusters of the pair that minimizes the measure are merged. Beaulieu and Goldberg (IEEE Trans. Pattern. Anal. Mach. Int., Vol. 11, pp. 150-163, 1989) show the importance of hierarchical clustering to solve precisely defined picture segmentation problem, such as 1) finding the partition witch minimizes the approximation error, or 2) making statistical decisions with the minimum probability of error.

In hierarchical segmentation, only adjacent segments could be merged, greatly reducing the number of segment pairs to compare. However, computing time could still be excessive. In the implementation of the algorithm, recalculation are avoided by 1) making explicit the information needed, and 2) updating the only values that are modified by a segment merger.

EFFICIENT IMPLEMENTATION

Data structures are employed to organize image data and to reduce computing time, memory space replacing CPU time. A descriptive structure, D_i, contains pixel value descriptive parameters for segment S_i, e.g. the segment mean and size. The criterion $C_{i,j}$ is calculated directly from D_i and D_j, e.g. mean difference. Moreover, when two segments are merged, the descriptive parameters, D_v, of the new segment are calculated from the old ones.

Each segment have also a neighbour list, B_i. The list is used to scan the segment pairs. For each segment S_i, we examine all its neighbours to find the one with the lowest criterion value, the best neighbour. The lowest criterion value is stored in a criterion list, Cr(i). A tree structure is employed to find the lowest value of the criterion list. When two segments are merged, the new neighbour list, B_v, is produced from the fusion of old neighbour lists. Thus, D_i and B_i contain all the required information about the image, no more reference to the image is needed.

After each merge, we find the best neighbour of the new segment, S_v, and store the criterion value in the criterion list. We then update the tree structure by going from the leaf node v to the top node. The top node corresponds now to the next best segment pair to merge. After a merge, the best neighbour of the surrounding segments should be recalculated. We check and do it only when the segment is selected for the next merge.

At each iteration, the labels of the two merged segments are stored into a merge list. From the complete merge list, a partition with n segments can be quickly obtained, where n is specified by the user. The computing time of the algorithm is mainly proportional to the initial number of segments (which often corresponds to the number of pixels in the picture).

VERSATILE SEGMENTATION

The versatility of the algorithm should also be stressed. The segment similarity criterion, $C_{i,j}$, could be easily adapted to the specific application. In remote sensing, a segment is generally represented by its mean value. Thus, picture segmentation could be regarded as a piecewise constant value approximation problem. It could also be advantageous to consider other aspects, such as the segment shape. Hence, following an approach similar to Brice and Fennema, a first criterion will limit the increase of the segment contour length. It promotes the merge of the segments with a large common boundary. A modification is made to the neighbour list, B_i, to contain also the boundary length. The other shape criterion promotes the formation of compact regions instead of elongated ones. This two shape criteria are combined with the constant approximation criterion in an heuristic manner. Segmentation results will be presented at the conference.