Automatic Contour Segmentation for Object Analysis

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Abstract

The problem of distinguishing shapes from a compound contour, which is formed by overlapping more than one distinct object, is considered. The algorithm exploits the fact that planar shapes can be completely described by contour segments, and that they can be decomposed at their maximum concavity into simpler objects. To reduce spurious decomposition, the decomposed segments are merged into groups by analyzing and utilizing the merging hypotheses. The algorithm calculates the linking possibility by weighting the angular differentiation which measures against k-curvature consistency. The techniques are implemented and are applied to other partial shape matching problems for clustering purposes.

1. Introduction

The problem described in this article is investigation of the decomposition of overlapped objects[4-5]. Object decomposition can be applied as one of the preprocessing steps for the recognition of objects. A considerable amount of earlier research in the field of partial recognition has been done [1-3, 6-7]. The typical technique they used for reference finding is exhaustive searching. In most cases, it suffers from the time-consuming bottleneck of exhaustive matching trials between the compound template and data shape. This study attempts to reduce the exhaustive matching load. Let's use the following example to define the problem.

Given M data shapes, \( \{S_i; i = 1,2,\ldots,M\} \), each of which has a set of \( n_i \) features, respectively. Let \( U \) be a test template; it can be considered as a compound shape within which the cluster \( S_p \) is overlapping with some other clusters. Assume that a total of \( n_u \) features are extracted from \( U \). Among them \( \hat{n}_p \) features belong to cluster \( S_p \). Since the template can be considered to be occluded and distorted, it is true that \( \hat{n}_p \leq n_p \). To establish matching between template and data shapes, the same number of \( r \) features should be selected from both the template and the given data sets, respectively. It is obvious that \( r \) should be less than or equal to the smallest number among \( n_i \) for \( i = 1,2,\ldots,M \). In the worst case, the total exhaustive trials can be counted as

\[
\sum_{i=1}^{M} \left( \frac{n_i!}{(n_i-r)! \cdot r!} \cdot \frac{n_i!}{(n_i-r)! \cdot r!} \right) \tag{1}
\]

On the other hand, the author's new approach decomposes the template into separate clusters, which are most likely to belong to only one of the data shapes, and of which each is individually analyzed as an independent template. Assume that \( N_r \) clusters are extracted from \( U \). The total exhaustive trials can be reduced to a total of

\[
\sum_{i=1}^{M} \frac{n_i!}{(n_i-r)! \cdot r!} \tag{2}
\]

where \( r_k \) is the number of features obtained from the \( k \)th cluster. It was proved that the number of Eq. (2) is less than that of Eq. (1).

2. Contour Decomposition

Local features describe limited portions of the shape and are unaffected by other regions of the object. If overlapping is the only concern, it is true that those regions which escape from being occluded are free from distortion. Shape decomposition is then mainly based on the above fact. The method presented in this paper uses simple-shaped curves to define local primitives. By a simple-shaped curve we mean a segment of contour with no significant curvature change. That is, the curvature function changes monotonically, or the amplitude of the varying is under a pre-determined tolerance.

In general, a planar curve does not behave like a single-valued function; a parametrical representation of a two-dimensional contour is used. A displacement method is employed to evaluate the significance of each point. It is clear that a significant corner should be a physical sharp part, and it might be either convex or concave. That is, a significant corner has a displacement which is a local maximum and a long segment of decreasing curvature is next to either side of it. The contour is split into segments at the significant corners. Each segment generated by the splitting is a simple-shaped curve and it is defined as a primitive. Thus, contour can be described as a linear combination of primitives which contain no significant curvature changes.

3. Contour Recomposition

Each primitive has two endings: leading- and lagging-points. They are denoted as \( \gamma \) and \( \gamma' \), respectively. Each primitive is compared to other primitives by its local k-curvature \( (\hat{\theta}_k) \) for best matching. The
hypothesis of merging is then established, based on the degree of disjunction which measures against k-curvature coherence.

A merge is legitimate if, and only if, two primitives are joined with consistent direction, that is, the leading point can only merge to a lagging point. A legitimate merge is denoted as $\pi_y$. If two primitives make a smooth curve, they should have a similar trend toward a curvature consistence. That is, the first derivative of the k-curvature ($\theta_k$) should be a constant or within a tolerable variance.

Let $\theta_0$ be an acute physical angle made by $\gamma_i$ and $\gamma_j$ and $d_{ij}$ be the distance between $\gamma_i$ and $\gamma_j$, respectively. Since the merge should be made against the k-curvature coherence, an adjustment for $\theta_0$ is needed. The calibrated angle $\alpha_{ij}$ is defined as

$$\alpha_{ij} = \theta_{ij} - \frac{1}{2} \left[ \theta_k(\gamma_i) + \theta_k(\gamma_j) \right] \times d_{ij}. \tag{3}$$

The probability of merge $p_{ij}$ (a generated hypothesis) is therefore given by the following expression:

$$p_{ij} = \frac{100}{1 + \left( \frac{\alpha_{ij}}{\theta_0} \right)^2} \% \quad \text{if} \quad \alpha_{ij} \geq \theta_0 \tag{4}$$

where $\theta_0$ is a merging constant which is referred to as the tolerance of disjunction. In our experimental study, this constant is set to be $20^\circ$. The highest probability occurs when $\gamma_i$, $\gamma_j$, and $\theta_0$ have the matching trend toward the merge. That is, $\theta_k(\gamma_i) = \theta_k(\gamma_j) = \theta_0$.

3.1 Confliction Test

It is inevitable that erroneous or redundant hypotheses were generated within previous procedures. Since the problem in which the author is interested is to solve the occluding, it is obvious that a merge is erroneous if there is no physical body embedded in the merging path; that is, there are holes or concave corners intersecting with the merge. A merge is redundant if there is at least one legitimate merge lying on its merging path.

3.2 Probability-Linking Test

It is obvious that merging primitives should be in a one-to-one and corresponding mapping fashion. This implies that no two non-zero entries can co-exist in any row and any column of the probability matrix. After the previous test (CT), the entry with the highest quantity will be considered as the candidate for merging. Since the hypothesis that two primitives make a convex corner is always true, the PLT test can be done by starting from a convex corner. One linking path is completed if it is a self-closed loop or if it meets a concave corner. Since the hypothesis that two primitives make a concave corner is highly uncertain, the merge will be considered legitimate only if both primitives can not make other merges.

4. Result and Conclusion

We have presented a technique for decomposing the overlapped or occluded shape into its components and recomposing the possible missing pieces back to their original form (see Fig. 1). The algorithm reduces the possible false matchings and simplifies the problem of partial shape recognition. The current implementation has only applied to the tools with simple curved shapes. In practice, two shapes still have high probability to be extracted as one object if both of them have the same curvature trend and happen to be overlapped in some particular orientation that makes them joined together smoothly. The technique failed in dealing with this kind of difficulty.

5. References