Tracking the Ballistic Trajectory in Complex and Long Handwritten Signatures

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Abstract

A novel proposal based on the principles of the Good Continuity Criteria is developed to address the writing order recovery. It is composed by three stages: 1. Point classification; 2. Local examination; 3. Global reconstruction. Our implementation focuses on a multiscale analysis of the thinned traces and the Dijkstra's algorithm for an effective branch association of the crosses produced by the stokes intertwining.

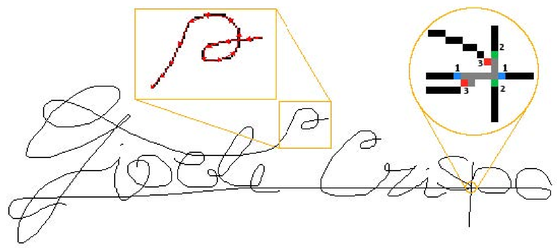

Figure 1: Example of branch association and writing order recovery in a complex and long Western handwritten signature.

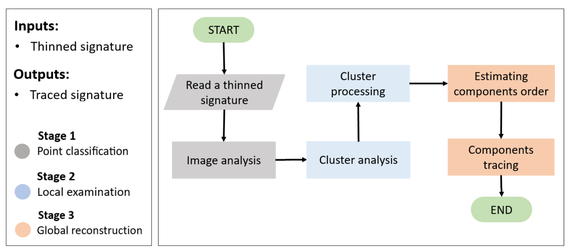

Figure 2: Overview of the proposed method, which is composed of three stages.

1. Point classification

Each pixel in the thinned signature-based image is labeled according to the number of its neighbors: end point (one neighbor); trace point (two neighbors); branch point (three or more neighbors). A cluster consists of an isolated set of connected branch points.

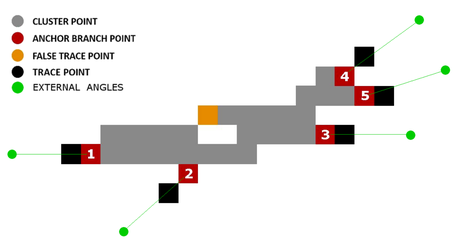

Figure 3: Example of a cluster and its analysis.

2. Local Examination

As shown in Figure 6, clusters can be composed of several elements: **cluster points**, simply branch points; **anchor branch points**, exit branch points; **false trace points**, trace points belonging to the cluster. In addition, the cluster external angles are defined. They characterize the exit directions through an angle. The calculation of external angles is performed through a multiscale approach considering 5 pixels from the anchor branch point. Clusters are classified based on their rank: **Even-rank clusters**, are processed using Good Continuity Criteria and **Odd-rank clusters**, which are decomposed in two simpler clusters. Once clusters branches have been associated the path between is computed through the Dijkstra's Algorithm.

Processing 3-rank clusters is a very tough operation, since a complete pairing of their branches is not possible. The analysis of their geometric and morphological properties helps us to classify them in one of the three cases shown in Figure 4.

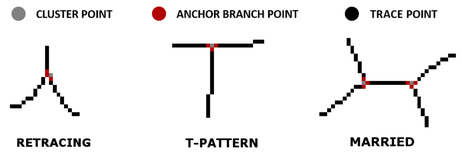

Figure 4: Classical topology of 3-rank clusters.

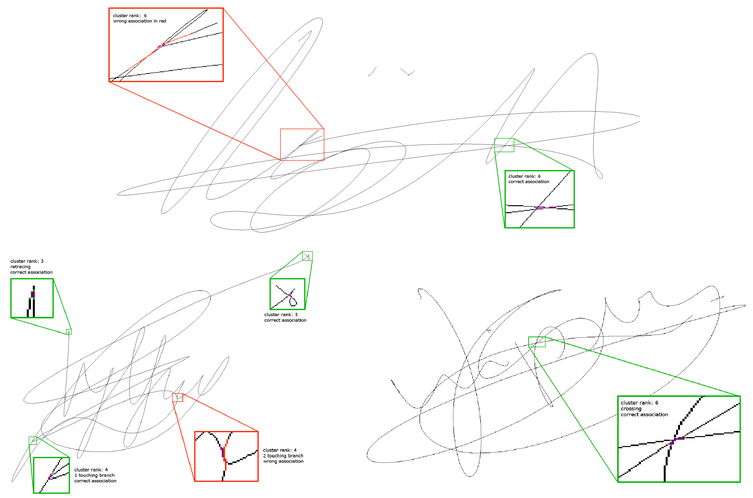

Figure 5: Local Examination: examples of cluster branch association.

3. Global Reconstruction

A critical issue in recovering the ballistic trajectory of signatures is to understand what is the starting point and how to select the components to trace. **Starting point selection**: to choose the starting point, we model with a two dimensional Gaussian function the starting point of 1593 signatures of SigComp2009 database. Then, the first point to trace is the end-point closer to the center of the Gaussian distribution. **Next component selection criterion**: once the first component is traced, the next component is chosen according to a proximity criterion, i.e. the one that includes the closer end point, which has not been traced yet.

$$i^* = \arg\min_{i \setminus j} \left(\sqrt{\left(x_{ep_i} - x_{ep_j}\right)^2 + \left(y_{ep_i} - y_{ep_j}\right)^2} \right) \quad (1)$$

where x_{ep_i}, y_{ep_i} are the coordinates of the last traced end point and x_{ep_j}, y_{ep_j} are the coordinates of the end points belonging to components not yet traced.

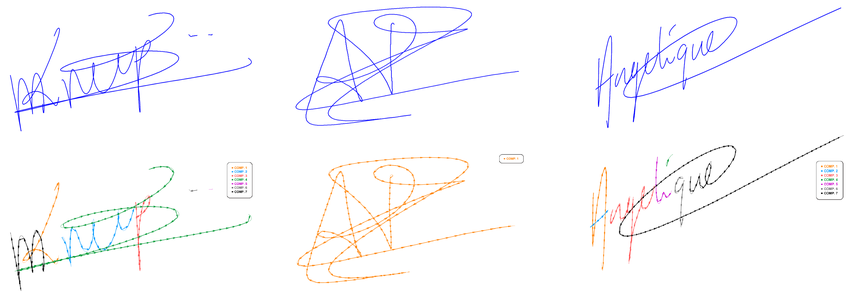

Figure 6: Global Reconstruction: thinned version (top), recovered one (bottom).

Results

To evaluate the performance we used as measuring meter: RMSE, DTW and the cluster resolution percentage (CRP), a new measure with the purpose of evaluating the number of correctly resolved clusters.

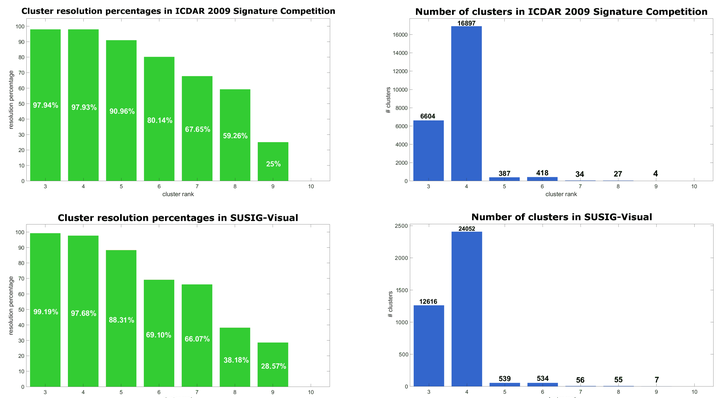

Figure 7: Performance results of the proposed method on the two databases, SigComp2009 (top), SUSIG-Visual (bottom). On the left, the bar charts showing the percentages of solved clusters; on the right, the bar charts showing the number of the clusters.

Database	Method	Task	Results		
			RMSE‡	DTW‡	CRP
Arabic Signatures [1]	Trajectory estimation as being the mean X vector and mean Y vector from the training	Competition on stroke recovery (ICDAR 2013) [1]: Skeletonization + WOR*	0.245	52.404	-
Single strokes [2]	Skeleton graph development, minimum pre-Hamiltonian path and stroke separation from smoothest paths [2]	WOR*	400.98	118.12	-
Multi strokes [2]		WOR*	503.81	171.91	-
Scanned words [2]		Skeletonization + WOR*	2538.05	533.57	-
IRONOFF† [3]		Skeletonization + WOR*	669.03	278.27	-
SigComp2009	Good Continuity Criteria by using the Dijkstra's algorithm on a multiscale analysis of the thinned traces **(this work)**	Cluster analysis and WOR*	0.0634	382.0143	98.55 %
SUSIG-Visual			0.0533	300.4985	98.70 %

*WOR stands for Writing Order Recovery. †It contains isolated characters, digits, and cursive words. ‡ Different formulas among the related works.

Table 1: Evaluation on recovering the writing order in handwritten signatures and comparison with other works.

References

[1] A. Hassaïne, S. Al Maadeed, and A. Bouridane, "ICDAR 2013 competition on handwriting stroke recovery from offline data," in *12th Int. Conf. on Document Analysis and Recognition (ICDAR)*, 2013, pp. 1412–1416.

[2] M. Dinh, H.-J. Yang, G.-S. Lee, S.-H. Kim, and L.-N. Do, "Recovery of drawing order from multi-stroke english handwritten images based on graph models and ambiguous zone analysis," *Expert Systems with Applications*, vol. 64, pp. 352–364, 2016.

[3] S. Al-maadeed, W. Ayouby, A. Hassaine, A. Almejali, A. Al-yazeedi, and R. Al-atiya, "Arabic signature verification dataset," in *Proceedings of the International Arab Conference on Information Technology*, 2012.