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Graph-Based Offline Signature Verification

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Handwritten signatures are used in everyday transactions and remain a widely accepted means of personal authentication, both culturally and legally. Automatic signature verification aims to establish whether or not a signature is genuine by means of a computer program. It is a challenging task, even for humans, as typically only a few genuine signatures are available as references for each user.

In order to process handwritten signatures algorithmically, they first need to be represented in a machine-interpretable way. Most current systems follow the statistical approach that represents scanned signatures using a fixed number of features, which are either handcrafted or learned from the data. A limitation of this representation formalism is that it does not offer a convenient way to model parts of a signature and their relations. Graph-based representations can overcome this limitation. The nodes of the graph represent different parts of the signature, while the edges model the relations of these parts within the global structure. However, graphs have only rarely been used for analyzing handwritten signatures in the past. One of the reasons is probably the high computational complexity of graph matching.

This thesis contributes to the research question of whether graph-based approaches are beneficial for the task of offline signature verification. For this purpose, we investigate two graph-based signature representations together with efficient matching methods, which have been proposed for handwriting analysis in the past. The first approach is based on skeleton graphs that are matched with efficient approximations of the graph edit distance. The second approach relies on tree structures, so-called inkball models. Inkball models leverage a specialized matching scheme that determines how much energy is needed to fit an inkball model to a signature image.

Based on these graph-based approaches, we introduce a structural writer-independent signature verification system. The parameters of the system are analyzed and optimized with respect to a series of experimental studies performed on a public dataset, which consists of synthetic signatures. In particular, we fine-tune the density of the graph nodes with respect to both verification performance and computational speed. Eventually, we test the system on four benchmark datasets for signature verification, namely GPDSsynthetic, MCYT-75, CEDAR, and UTSig, and compare its performance with the current state of the art.

In recent years, neural networks have revolutionized statistical pattern recognition and play a central role in the current state of the art. Therefore, we also study a neural-network-based approach in the context of this thesis and compare it with our graph-based methods. Specifically, we use convolutional neural networks to learn a feature vector representation of signature images using a triplet loss function and employ the Euclidean distance in the embedding space for verification. We compare and combine this statistical approach with our structural signature verification approaches.

Our work shows that a graph-based signature verification system can achieve state-of-the-art results. The experiments highlight further that graph-based approaches work well in combination with statistical approaches due to their complementary perspectives on handwritten signatures.

The general framework for structural signature verification proposed in this thesis provides a promising starting point for more research into graph-based approaches. The graph-edit-distance-based method, in particular, can be used in conjunction with any type of labeled graph. We would expect that the integration of more domain knowledge from forensic experts into the graph-based representations may further improve the robustness and interpretability of automatic signature verification.

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