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FEATURE EXTRACTION METHODS FOR OFFLINE SIGNATURE VERIFICATION: A REVIEW

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Abstract: As signatures continue to play an important role in financial, commercial and legal transactions, truly secured authentication becomes more and more crucial. The benefits of an automatic handwriting recognition system have long been known. A handwritten signature is a kind of agreement. Mostly, it is an agreement with the content of a document. It can be the signature on a contract, an application for an official document. Feature extraction and representation is a crucial step for pattern recognition problems. Extraction of features that represent the intrinsic content of the images as complete as possible is still a challenging problem. However, enormous approaches have emerged to solve this problem .This paper presents a review of the most common techniques for feature extraction and explores opportunities for further research and development of novel techniques for the said problem. This study showed that fusion of global and local features may lead to better results for offline signature recognition and verification. Finally, authors summarize the paper with some important conclusions and point out the future potential research directions.

Keywords: Statistical Features, Grid features, String matching, Discrete Wavelet Transform, Modified Direction Features, Geometric features

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INTRODUCTION

Signature verification is the emerging biometrical identification method, with a high legal acceptance. Although handwritten signature verification has been extensively explored in the past decades, and even with the best methodologies functioning at high accuracy rates, there are a lot of future research opportunities. Signature verification and recognition systems are categorized as online and offline systems. Online signature verification and recognition systems take advantage of dynamic features like acceleration, velocity and the difference between up and down strokes.

However, in the most common real-world scenarios, this information is not available, because it requires the observation and recording of the signing process. This is the main reason, why off-line signature analysis is still in focus of many researchers. Off-line methods do not require special acquisition hardware, just a pen and a paper, they are therefore less invasive and more user friendly. In the past decade a lot of solutions have been proposed, to overcome the limitations of off-line signature verification and to compensate for the loss of accuracy. Most of these methods have one in common: they deliver acceptable results, but they have problems improving them.

Handwritten signatures come in many different forms and there is a great deal of variability even in signatures of people who use the same language. Some people simply write their name while others may have signatures that are only vaguely related to their name, some signatures may be quite complex while others are simple and appear as if they may be forged easily. It is also interesting to note that the signature style of individuals relates to the environment in which the individual developed their signature.

It is known that no two genuine signatures of a person are precisely the same and some signature experts note that if two signatures of the same person written on paper were identical they could be considered forgery by tracing. The signature of an individual change temporarily in the aforementioned attributes under different circumstances, e.g. the available space for signing. These variations can be minimized by normalization operation as a part of preprocessing [1].

HISTORY

The problem of signature recognition is broadly classified as: offline and online. The former methods analyse the static picture of the signature, whilst the later techniques consider the dynamics of the writing process [2]. The algorithms that take into account only the static image are vulnerable to forgeries, but in many cases the static image of the signature is the only available form of information. This paper presents a literature review of feature extraction methods for offline handwritten signature.

Many research efforts have been contributed to handwritten signature recognition (HSR). Research on offline HSR began in the late 1970s and has attracted high attention from 1980s. [3]. Many effective methods have been proposed to solve this problem, and the recognition performance has advanced significantly. Fig. 1 shows a typical signature recognition system.

- Statistical classification :

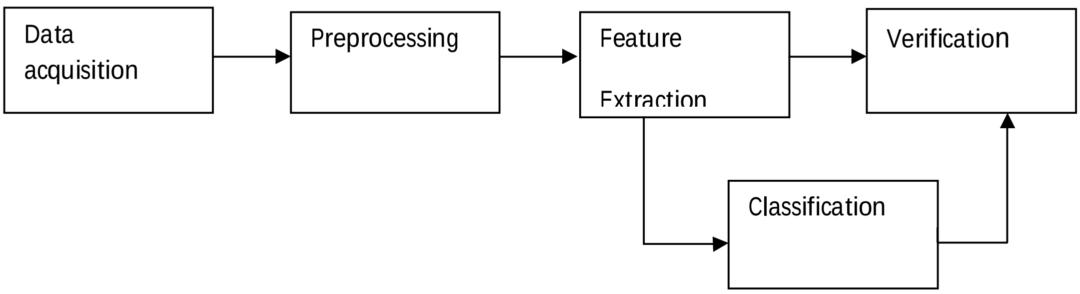

Figure 1: Typical signature recognition system

There are mainly two approaches to HSR:

- This is based on the feature vector representation of character patterns.
- Compute a distance measures such as Euclidian distance or city block distance between the test pattern and the class prototype.
- Use correlation matching
- Deploys sophisticated classification techniques such as parametric and nonparametric statistical classifiers, Neural networks, Support vector machines (SVMs) etc.
- Selection and extraction of features is a critical issue.

 Structural classification

- Inverse process of character generation. Process of computing structural distance measure between the test pattern and class models.
- Exploits human cognition and potential for absorbing large deformation.
- Suffers from difficulty in stroke extraction and building structural model.

The following factors enhance success of statistical approaches:

- Simple implementation of feature extraction based on template matching and classification based on feature vector computation.
- Effective image normalization and feature extraction techniques improve classification ability in feature space.
- Machine learning methods that enable classifier training with a large set of samples for better discrimination of shapes in different classes [3].

III. REVIEW OF FEATURE EXTRACTION METHODS

This section presents the current approaches for verification of signatures in offline mode as shown by fig. 2. Several steps are performed for verification or identification of a signature. Preprocessing is followed by conversion of all signatures in the database to a portable bitmap format [6]. Suitable operations extract boundaries to facilitate the extraction of features. Verification experiments are performed with neural-based classifiers.

A. Angle Feature Algorithms

More recent approaches include angle feature algorithm [4] to extract features of signatures, using Generalized Regression Neural Network (GRNN) which is often used for function approximation. It has a radial basis layer and a special linear layer. This paper [4] claims better results than Discrete Cosine Transform (DCT) however; it takes relatively more time than DCT. Angle features vary with changes in the block size, resulting into changes in performance.

B. Geometric Features

Another approach presents a set of geometric signature features for offline automatic signature verification based on the description of the signature envelope and the interior stroke distribution in polar and Cartesian coordinates. The features have been calculated using 16 bit fixed-point arithmetic and tested with different classifiers, such as hidden Markov models, support vector machines, and Euclidean distance classifier. The experiments have shown promising results in the task of discriminating random and simple forgeries [5]. The geometrical features proposed by this method are based on two vectors which represent the envelope description and the interior stroke distribution in polar and Cartesian coordinates.

C. Extraction of Statistical Parameters

One of the recent papers presents extraction of extent, solidity, number of objects, major axis length, Equivalent diameter, area, convex area, orientation and Euler number that can distinguish signatures of different persons [7]. Few statistical characteristics are seen as extracted features in [8]. These features are found as follows:

- Signature Height ,Width Ratio
- Signature Occupancy Ratio
- Distance Ratio calculation at boundary
- Ratio of Adjacency Columns
- Number of spatial symbols within the signature image

This method [8] shows the simple yet reliable solution to the problem of signature recognition and verification.

D. Dimensionality Reduction

Furthermore a novel approach of reducing the dimensionality of data that is a very important phase of every recognition process is found in [9]. Static analysis deals with the matrix representing the signature image. In order to reduce the size of data while preserving the general features the view-based method is applied first. The algorithm chooses only those points with minimal and maximal value of y coordinate.

E. Grid Features

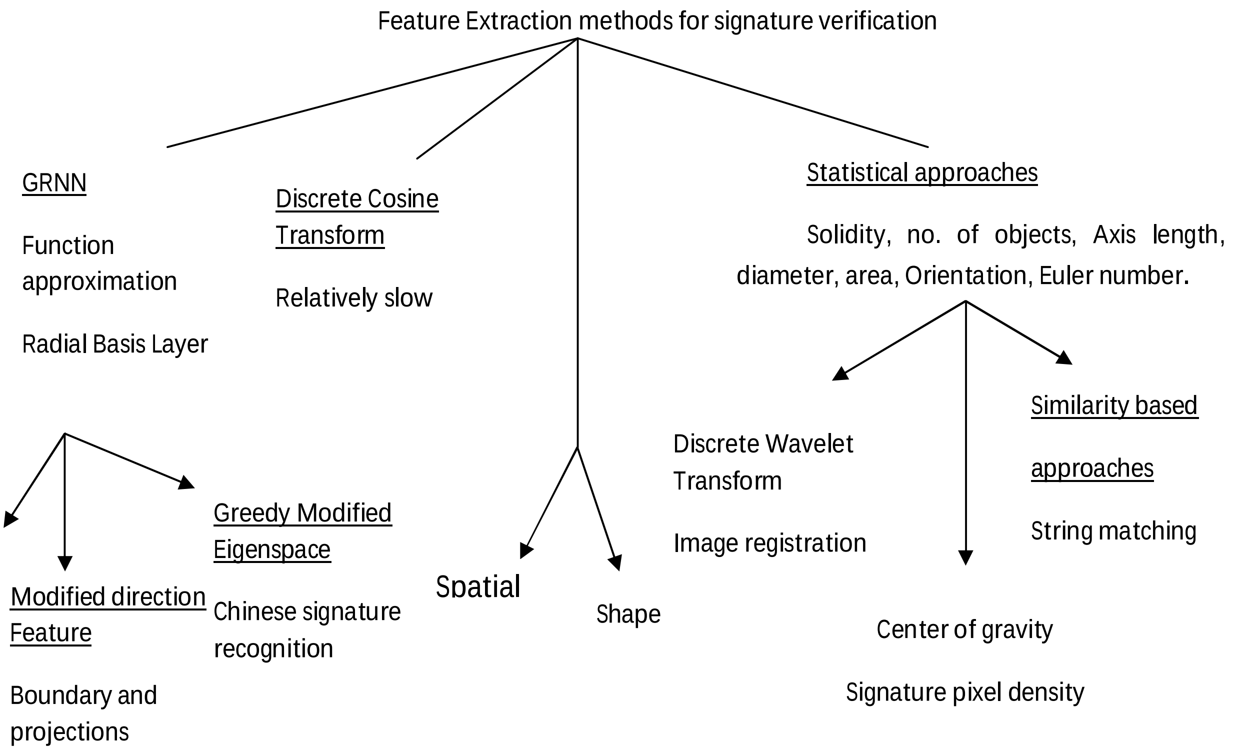

Figure 2: Feature extraction methods for signature recognition

A similar set of features including proportion factor, center of gravity and horizontal, vertical signature pixel density is presented [15]. This approach further uses grid features for finding densities of signature parts. Sixty grid features by dividing signature into sixty equal parts and the image area in each divided part is calculated.

F .Graphs

The graphs representing signatures belonging to a particular individual fit closely together, allowing for easier recognition. The study shows that such a system should be supplemented by additional data from local features like placement and size of internal loops, number of crossings, endings and so on. This survey [9] opens opportunities for the future research focusing on incorporating both global and local features in one hybrid solution.

G. Similarity Based Approaches

A similarity based approach between an input signature and the reference set is computed using string matching and the similarity value is compared to a threshold [10]. Several approaches for obtaining the optimal threshold value from the reference set are investigated. All strokes are combined into one long stroke during preprocessing. The original number of strokes is recorded and used as a global feature. From the x- and y-coordinates of the preprocessed image, a number of local features are extracted which are divided into two categories, spatial and temporal features. Spatial features are static features that are extracted from the shape of the signature.

H. String Matching Ttechniques

The signatures are represented as a string, i.e., a sequence of feature vectors whose size is the number of local features extracted [10]. Global features are not included in this representation. String matching, also known as dynamic time warping, is a well-known method to compare strings of different lengths. It finds an alignment between the points in the two strings such that the sum of the differences between each pair of aligned points is minimal. To find the minimal difference, all possible alignments must be investigated. An efficient solution for this is based on dynamic programming. This method of string matching extends the basic approach by adding a method of allowing strings with broken strokes to be reconnected, while including a penalty to discourage the matching of two strings with large differences in the number of strokes detected [10].

I. Signature Processing of Oriental Scripts

An off-line signature verification and validation system for Arabic handwritten signatures is proposed [11]; based on Discrete Wavelet Transform (DWT). The significance of image registration is deployed in [11]. The registration step contains three operations; scaling, shifting and rotating. These steps are followed by a shifting operation using the center of gravity (COG) to determine the centric of the signature. The rotation operation is then performed to align signature in the correct direction. Discrete Wavelet Transform (DWT), reduction method, and common features method are applied to extract the features before the verification step. The method presents logical operations with mathematical formulae to verify signatures. The experimental results were satisfactory and showed improvements over many recent works.

Grid features have been used extensively in the off-line signature recognition and verification approach. The signature image is divided into many rectangular segments (often 12×8, 15×8 segments), and for each segment, the area (the sum of foreground pixels) is calculated. A Complex problem of Uyghur handwritten signature is presented in [12]. A multi-dimensional modified grid information features are extracted according to the character of Uyghur signature and its writing style. This method uses three kinds of classification techniques: Euclidean distance (ED) classifier, K nearest neighbor (K-NN) classifier and Bayes classifier.

J. Modified Direction Features (MDF)

The performance of the Modified Direction Feature (MDF) feature extraction technique in conjunction with three other simple global features has been investigated. Global features based on the boundary of a signature and its projections are described for enhancing the process of automated signature verification [13]. The first global feature is derived from the total 'energy' a writer uses to create their signature. The second feature employs information from the vertical and horizontal projections of a signature, focusing on the proportion of the distance between key strokes in the image, and the height/width of the signature.

The combination of these features with the MDF and the ratio feature showed promising results for the off-line signature verification problem [13].

K. Stroke Analysis

Next a simple and efficient off-line approach to signature recognition is presented [14]. The technique is based on an approximate feature extraction of relevant component strokes for a given test signature. Each extracted stroke is represented by a set of only three features: its two endpoints and its global orientation. This information is efficiently compared with the corresponding patterns stored in the signature database, using a Euclidean feature matching approach, to find the most similar one to the query. The corresponding degree of similarity is also computed. This method considers the practical involved problems and requirements described in automatic verification systems, such as: lack of training samples, variability of signature patterns, presence of forgeries, robustness to moderate noise, and an acceptable response time. The system [14] can also be adapted for different internet applications i.e. e-commerce.

Many researchers continue to rely on geometric features. A paper based on two sets of points in a two-dimensional plane, each set having six feature points which represents the stroke distribution of signature pixels in an image is presented [16]. These twelve feature points are calculated by Geometric Center, vertical splitting and horizontal splitting. This method performs much better than any other off-line signature verification methods. Future opportunity in this is classifying the skilled forgeries correctly. This can be achieved by employing vertical and horizontal splitting to depth 2.

A new *Greedy Modular Eigenspace* (GME) is used as a feature extractor for Chinese signature recognition in comparison with the conventional feature extraction methods [17]. The approach is designed to extract the simplest and the most efficient signature feature modules collected from each signature with a very large dimensional signature feature dataset which include real-stroke and virtual stroke features. The *feature scale uniformity transformation* (FSUT) is then performed to fuse most correlated signature features from different signer datasets. By modifying the correlation coefficient matrix operations, GME improves the performance in signature feature extraction. After the feature extraction stage, FUST is implemented to reduce dimensionality of the signature feature. The performance of the proposed method is evaluated by applying to an experimental signature database. The experiments demonstrated that the proposed GME/FUST method is not only an effective scheme of the feature extraction, but also reduces the computational complexity of the signature recognition.

Offline signature verification is implemented using statistical parameters and features from right, left, upper and lower envelopes extracted from signature image, and an array of five growing cell multilayer neural networks [18]. This approach exhibits a fairly good recognition rate with a relatively low computational complexity.

A different approach is seen where the problem of signature recognition is separated from signature verification. They are treated as two separate and consecutive phases. Successful verification is highly dependent on successful recognition. Therefore, the features used during the recognition phase are not the same as those used later during the verification phase [19].

IV .Conclusion

Authors discussed a problem of personal authentication through the use of signature recognition. Major off-line methods have been reviewed. The driving force of the progress in this field is, above all, the growing role of the online financial and legal transactions in modern society. Therefore, a considerable number of applications are concentrated in the area of electronic commerce and electronic banking systems. Among off-line methods the following techniques have been reviewed: 2D transforms, histograms of directional data, curvature, horizontal and vertical projections of the writing trace of the signature, structural approaches, local measurements made on the writing trace of the signature, the position of feature points located on the skeleton of the signature.

Authors conclude that machine recognition and verification of signatures is a very special and difficult problem. The difficulty seems to arise from the following:

i) The inherent complexity of signature patterns and the wide variation in the patterns of an individual person as there is no unique ideal shape for any individual person. ii) The visual similarity of forged signatures produced by professional forgers with the original. It's quite difficult to discriminate even for a well-trained and examiner. iii) The external environment under which the signature is acquired may seriously affect the quality of the signature. iv) Lack of efficient retrieval methods of signatures in the large database. This becomes especially difficult as no pre-established class is created for forged signatures while database creation.

Although no single approach to feature extraction is proved to be the efficient mechanism, its significance in achieving good results is still justified. Thus, hybrid methods to capture statistical structural and other geometric characteristics of signature shape have still a very promising future.

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