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A robust method for coarse classifier construction from a large number of basic recognizers for on-line handwritten Chinese/Japanese character recognition

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ABSTRACT

In this paper, a systematic method is described that constructs an efficient and a robust coarse classifier from a large number of basic recognizers obtained by different parameters of feature extraction, different discriminant methods or functions, etc. The architecture of the coarse classification is a sequential cascade of basic recognizers that reduces the candidates after each basic recognizer. A genetic algorithm determines the best cascade with the best speed and highest performance. The method was applied for on-line handwritten Chinese and Japanese character recognitions. We produced hundreds of basic recognizers with different classification costs and different classification accuracies by changing parameters of feature extraction and discriminant functions. From these basic recognizers, we obtained a rather simple two-stage cascade, resulting in the whole recognition time being reduced largely while maintaining classification and recognition rates.

1. Introduction

Due to the development and proliferation of pen-based or touch-based input devices such as tablet terminals, smart phones, electronic whiteboards, and digital pens (e.g., the Anoto pen), on-line handwritten character recognition is receiving even more attention than before.

Although character classifiers with high recognition accuracy have been reported [1–5], the demand for speeding up recognition is very high for portable devices as well as for desktop applications for which handwriting recognition is incorporated as one of the modules. The performance of these relatively small devices requires having a fast as possible recognition speed while maintaining high accuracy. Even for a desktop PC with relatively high performance, a recognition speed of within 0.5 s per page is required in actual applications. Therefore, we need to refine the recognition scheme to improve the processing speed.

Chinese, Japanese, or Korean has thousands of different categories, and their large character set is problematic not only for the recognition rate but also for the recognition speed. A general approach to improving the recognition speed is to perform coarse classification, pre-classification, or candidate selection before the fine classification [6,7].

The coarse classification typically uses simpler classification algorithms or fewer features in order to achieve a better speed than does the fine classification. It is used to select a relatively small subset of candidates out of a very large set quickly. The fine classification would then be used on these candidates to match an input pattern so that the whole recognition time is reduced. Current approaches for coarse classification typically use distance measures that are simpler than those for fine classification [8,9]. The confidence evaluation provides even more precise candidate selection [10]. Others use simple features different from those for fine classification [11].

Sequential (multi-stage) classifications using a partial set of features at each stage have also been used [12]. A common characteristic of these methods is that the entire candidate selection process is performed during the recognition process. We call these “dynamic approaches.”

In contrast to dynamic approaches, prototypes may be organized prior to the search itself so that the search is performed on a subset of prototypes. We could mention a number of methodologies that vary slightly in how the data are organized. The simplest ones are proposals for ordered spaces and tree structures. The search on pre-structured spaces aims particularly at alleviating problems with search costs. As a result, recognition is accelerated. We refer to these methods as “static approaches.” In previous research within our group, we applied a static approach named “structuring search

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space" (SSS) for an off-line recognizer of handwritten Japanese characters [13,14]. In SSS, prototypes are organized by unsupervised clusters, and their centroids, for example, are used to represent the group. During recognition, an input pattern is first compared with all the clusters' centroids, and second, only the clusters with centroids similar to the input are used as search space. This method was extended to a two-layered search space [15] and named the "layered search spaces (LSS) method," which will be detailed later. Being different from the approach by Tseng et al. [16] and that by Fujimoto et al. [17], the LSS method works in the original feature space for fine classification and, therefore, only has to assume one distance space. Waizumi et al. [18] also presented a multilayer search space construction method for character class prototypes that uses LVQ.

In general, the previous methods for both the dynamic and static approaches have applied rather intuitive ideas for selecting simple recognition functions such as Euclidean distance or fewer features to speed up recognition. Therefore, they have to take a larger number of output candidates to maintain recognition rates, which causes recognition time to increase and limits the effects on speedup.

In this paper, we present a systematic method for constructing an efficient and a robust coarse classifier that uses a genetic algorithm (GA) for the on-line recognition of handwritten Chinese and Japanese characters. By preparing a sufficient number of basic recognizers, placing them in cascade architecture and employing GA to find the best components and parameters, we can find a better coarse classifier than previously employed methods. We can create many basic recognizers with different classification costs and different classification accuracies by controlling the parameters of feature extraction and discriminant functions which have been used for fine classification such as the modified quadratic discriminant function (MQDF). If we set the parameters different from their optimal values for fine classification, it may degrade the top recognition rate but speed up recognition with smaller memory cost, and retain the correct candidate within top-N by setting N large enough. We previously tried to find a combination of several base classifiers heuristically, but we were quite unsure on whether we had obtained the best combination. To solve the problem, we have moved to propose a method to construct a coarse classifier based on a cascade of many basic recognizers.

For on-line handwritten Chinese and Japanese characters, we prepare 243 basic recognizers with different classification costs and different classification accuracies by controlling the parameters of feature extraction and discriminant functions as well as the LSS method. Then, we construct a sequential cascade of basic recognizers and reduce the candidates after each basic recognizer. The parameters for the cascade of basic recognizers are estimated by using GA so as to optimize the holistic character recognition performance. The more the basic recognizers are, the better the accuracy of the cascade of basic recognizers can be optimized by GA which minimizes runtime while maintaining the recognition accuracy. The resultant architecture may be made of a few components, but we are more confident that it is best among many choices. The coarse classifier thus developed follows the dynamic approach although it integrates the statistically tuned LSS. Experimental results for the CASIA-OLHWDB1.1 database (on-line Chinese handwriting database) [19] and those for the TUAT Nakayosi/Kuchibue database (on-line Japanese handwriting database) [20] demonstrate the superiority of our method.

This paper is an extension to the conference paper [21]. We added more details of background and objective, extended technical description and also added extensive experimental results by applying our coarse classification method to three fine recognizers for the above Chinese and Japanese handwriting databases to demonstrate the applicability of our proposed method. The rest of this paper is organized as follows. In Section 2, an overview of our on-line handwritten character recognition system is presented. In Section 3, a linear structure for constructing a coarse classifier is designed, and in Section 4, a parameter optimization method is described. In Section 5, experimental results are presented, and in Section 6, our conclusion is presented.

2. Recognition system overview

2.1. Recognition system

We process each on-line character pattern as shown in Fig. 1. There are thousands of categories in the Chinese and also in the Japanese language. First, to improve the recognition speed, we reduce recognition candidates by using a coarse classifier for each on-line character input pattern. Then, we select a smaller category set from the candidates' output by using a fine classifier.

The fine classifier is in fact one of the modules used for handwritten text recognition [1], and it is combined with a segmentation module, geometric context processor, and a linguistic postprocessor.

2.2. Fine classification

Fine classification after coarse classification can be a structural recognizer [4,5] that uses structural features such as sampling points, line segments and/or strokes, or an un-structural recognizer [3] that uses un-structural features such as directional features and gradient histogram features. For on-line recognition, structural features are often employed with hidden Markov models (HMMs) or Markov random field (MRF) [4,5]. Since un-structural features are easily extracted from an on-line handwritten pattern by discarding temporal and structural information, we can also apply an un-structural recognizer [3]. The modified quadratic discriminant function (MQDF) [22] is often employed for Japanese and Chinese character recognition. Structural recognizers and un-structural recognizers have their advantages and disadvantages. For justifying our proposed approach for coarse classification and demonstrating the applicability of the idea, we apply our coarse classification method to three fine recognizers that are a structural MRF recognizer, a structural HMM recognizer and an un-structural MQDF recognizer for both the CASIA-OLHWDB1.1 database and the TUAT Nakayosi/Kuchibue database.

For the structural recognizers, we extract feature points along the pen-tip trace from pen-down to pen-up. We use the coordinates of feature points as unary features and the differences in coordinates between the neighboring feature points as binary features. We then use a MRF model or a HMM model [5] to match the feature points with the states of each character class of the input candidates produced by the coarse classifier and obtain similarity for each character class. We then select the top character categories with the largest similarities as the output candidates of the fine classifier. For the HMM recognizer, we merged the binary

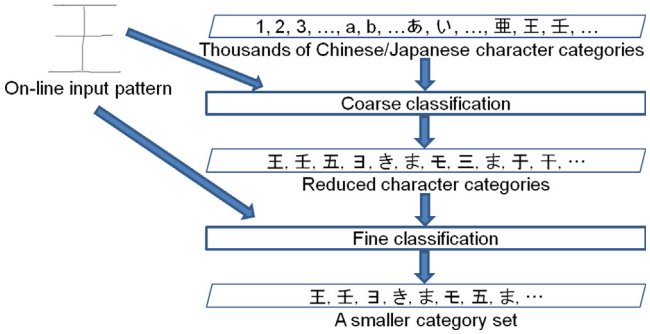

Fig. 1. On-line handwritten character recognition. First, recognition candidates are reduced by using a coarse classifier. Then, a smaller category set is selected by using a fine classifier.