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The Recognition of Printed Korean Characters by ART-Based Neural Network Hierarchy

Yong Tae Woo*, Ji Hyun Kim*, Bong Goo Lee*, Nam Il Lee**

* Dept. of Computer Science, Changwon National Univ. Korea

** Dept. of Computer Engineering, Andong National Univ. Korea

ABSTRACT

In the studies of Korean character recognition, the classification of characters by their structural types has been the most common approach; Korean characters have 6 different structural types and are written with 24 letters of the Korean alphabet in rectangular shapes. Because of this structural characteristic of Korean characters, most conventional approaches first classify the structural types of the Korean characters. When the structural types are classified, the component letters are separated. However, with various fonts and sizes, the component letters are often closely connected; and so they are hard to separate and to classify. In this paper, we propose a new approach which is not based on the conventional method of separation of component letters from structural types to recognize printed Korean characters. The new approach is based on a hierarchical neural network system consisting of ART(Adaptive Resonance Theory) neural networks and uses diverse features of Korean characters which can be classified irrespective of various fonts and sizes.

Introduction

Approaches which have been used for Korean character recognition are using structural, statistical and neural approaches[1-4]. In particular, in areas such as character recognition, where the application of mathematical analysis is difficult, neural approaches have been effective through learning processes. There are two approaches to constructing input for character recognition. One uses the whole image of a character. The other one extracts features that best represent a character. Both of these approaches have disadvantages. The first approach requires a lot of computations, whereas the second one requires to have a good selection of features that best describe a character; the effectiveness of character recognition depends on the features that have been selected.

In the Korean alphabet, there are 24 letters of which 14 are consonants and 10 are vowels. It is possible to construct 11,172 characters with the letters of the alphabet, but 1300 characters are currently being used. Most conventional approaches to Korean character recognition have considered the 6 different structural types of Korean characters[5]. When the structural types were realized, the component letters were separated for character recognition. However, the separation of component letters was not always an easy task; with various fonts and sizes, some component letters were closely connected to each other; and so they are hard to separate and to classify. Hence, such approaches did not always have good performance.

There are other approaches to Korean character recognition. Instead of separating component letters, it uses a whole character as a unit for character recognition. In this approach, it uses a hierarchical classification to reduce the searching space. The first stage classifies characters having similar features and other stages following after that classify each different group of characters.

In this paper, we propose a new approach that uses an ART based neural network hierarchy which consists of 2 ART1 modules. In Stage 1, we have classified characters with similar features in order to reduce the searching space for the next stage. Since any error that may occur in Stage 1, would bring about a poor overall classification rate. We have extracted a feature vector which is invariant with respect to various fonts and sizes. These feature vectors are used as input to ART1 module.

Then Stage 2 classifies characters using each group of clusters with similar structural features. The clusters will have a horizontal or vertical vowel or a hole in common. These common features are removed included in every character within each cluster and four directional features that are bigger than a certain threshold value are extracted from the normalized input data to construct another set of feature vectors. These feature vectors are used as input to ART1 module for detailed classification.

ART for the Character Recognition

We have used an ART1 neural network system which is proposed by Grossberg for unsupervised learning[6][7]. ART1 neural network based on the chemical synapse

model is capable of self-organizing and self-stabilizing its recognition codes in response to many binary input patterns of variable complexity in real time. It directly accesses the recognition codes that can represent most of the binary input patterns after self-stabilizing. Moreover, it has overcome the Stability-Plasticity Dilemma which other neural network models tried to solve. It has proposed the solution to learning which should not forget what has been learned previously and can adjust to new situations without any supervision. It has been applied to the fields of character recognition where binary image inputs are used[8][9].

The following diagram of Figure 1 shows the operation of an ART based neural network hierarchy.

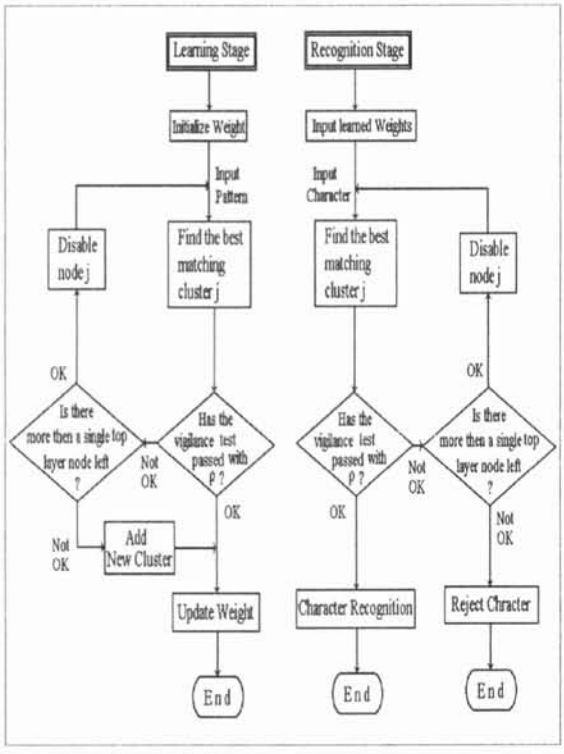

Fig.1 Operation of an ART based neural network hierarchy

ART-Based Neural Network Hierarchy

We have incorporated two stages in our hierarchial character recognition system for effective classification of Korean characters. Each stage consists of an ART1 neural network system. The following describes our ART-based neural hierarchy. We first have removed noise from the input data and normalized it to a 40x40 matrix. Then we have extracted features that are relevant for classifying characters. Then we have used these features as input to Stage 1 and classified characters with similar features. For characters in each cluster created from Stage 1, we have removed features that are in common and extracted 4 directional features. These features are used as input data for Stage 2 of our hierarchical Korean character recognition system. The overview of the ART-based neural network hierarchy is shown in the following diagram of Figure 2.

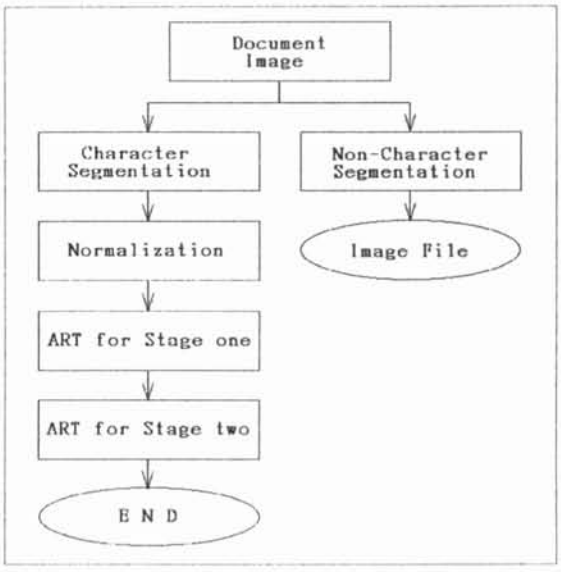

Figure 2. The overview of ART based neural network hierarchy

Normalization and Feature Extraction

The following describes how we approached the feature extraction. First, we modified the strokes to the same thickness by taking the size of the characters into consideration and normalized the size of the characters to 40x40 matrices[10]. Then, a character is scanned horizontally, vertically and diagonally from left to right and vice versa. The features which we call directional features from here onwards, are extracted from scanning and represent the strokes parallel to the lines of scanning. Strokes whose length are longer than a multiple value of certain thickness are extracted and represented by matrix notation. Then overlapping these features removes the noise and determines the 4 directional features. These matrices are summed and normalized to a 10x10 matrix.

In hierarchical classification approaches, error in Stage 1 would lower the efficiency of overall recognition rate. Hence, it is important to select invariant features independent of various fonts and sizes.

Korean characters are constructed with consonants and vowels of Korean alphabet. Korean characters are also constructed in rectangular shapes such that vowels are placed vertically in the rightmost part or horizontally in the middle or in the bottom. Hence, the knowledge of position of vowels can be used to set up regions to extract features from the normalized 40x40

matrix. By setting up the variable regions and using the 4 directional features, it is possible to extract structural features such as a vertical or horizontal vowel or a hole. These features are invariant and are independent of various fonts and sizes. The following diagram of Figure 3 shows the variable regions which have been set up to extract similar structural features.

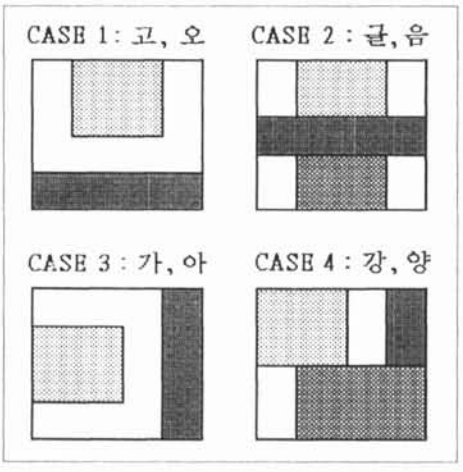

Fig. 3 Variable regions to extract features

Stage 1 : Rough Classification

The rough classification in Stage 1 is required to reduce the searching space for the following stage. Hence, it first classifies the characters by similar features. In the process of feature extraction, we constructed feature vectors and input to ART1 module and consequently obtained 17 categories of characters having similar features using 500 mostly used Korean characters printed in roman and gothic fonts.

In ART1 neural network, the vigilance parameter ρ can be a value between 0 and 1 depending on the measure of similarity between the input pattern and the categorized template. Hence, it is important to select the optimal value for the vigilance parameter when using an ART1 neural network for character recognition.

To select the optimal value of vigilance parameter for Stage 1, we changed the value of vigilance each time we executed the learning phase using the feature vectors. Figure 4 shows the changes in the number of categories with respect to the changes in the values of vigilance parameter. From this figure, we can observe that when we use values larger than 0.8, we do not see any changes in the number of categories. Hence, we have chosen 0.8 to be the optimal value we can use for the vigilance parameter. Table 1 shows the result of classifying from Stage 1 by feature vectors using 500 mostly used Korean characters printed in roman and gothic fonts.

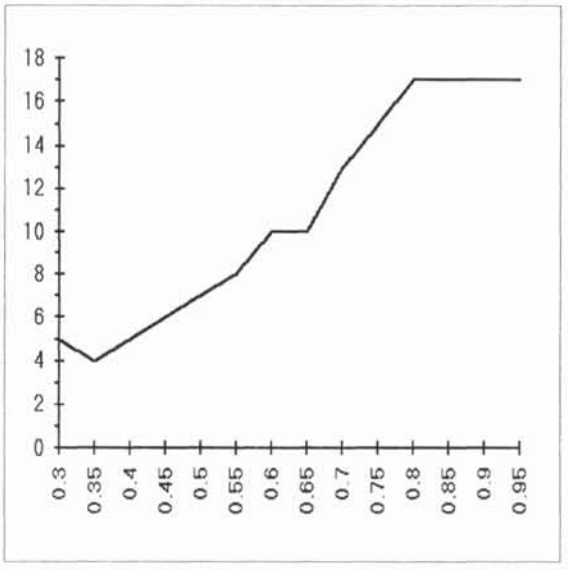

Fig.4 Categories according to the changes of vigilance parameter

No.	Rough classification results
1	고로도그조교소스노르드토초느트크료코 ...
2	으보요모오호또표포프므브효
3	는국수주구근족속두든독근극추준축규누 ...
4	를들출투특튼록론술루돌늘류쁜끝골굴줄 ...
5	을은부문우무유분운본불물욱북후못목온 ...
6	동궁종통등금중급증숭충농종능놓습틈높 ...
7	용음품읍풍움봉응옹홍몸
8	이의하어아여위화회와피뫼며허야마바외 ...
9	에해때배예애매폐쩨메베왜폐
10	다가지서기사나리자시과라되니러치거러 ...
11	대제게계네세개데체재래태새께레채네레 ...
12	한있인원만민면었학안했반역였연현약및 ...
13	일할발말월팔열알필별얼밀벌옐떨밝
14	평행없방않업양영임평입합법함향협형많 ...
15	정상성장경생당남강심령감집쟁점김람립 ...
16	것제적전선신관년간단진산된작력식견던 ...
17	실결같설달질철날절뒬길살잘걸갈찰칠갈 ...

Table 1. Rough classification results in Stage 1

Stage 2 : Details Classification

In Stage 1, we classify the characters in each category. They have common features such as a horizontal or vertical vowel or a hole. These features are not needed in this stage as they have used in the previous stage to create categories of similar features. Hence, they are removed from the input image. From the remaining binary

patterns, we have extracted 4 directional features which are bigger than a certain threshold value and constructed a new set of structural feature vectors of size 10x10 for Stage 2. Then these feature vectors are used as input to ART1 module in Stage 2.

Experimental Results

We have verified the new approach to printed Korean character recognition. During learning phase in Stage 1 for rough classification, we have used two different sizes of 500 Korean characters printed in roman and gothic fonts. During the execution phase, we have used 3 different fonts in two different sizes which are not used in the learning phases. The learning phase has produced 17 categories when 0.8 was selected for the vigilance parameter. Each category has 29 characters on average. However we have detected errors with characters like "앞". The occurrence of errors can be explained by differences of features in fonts. The correct classification rates in Stage 1 are 99% on average using different data. Hence, we can see that the new approach is efficient. Table 2 shows the result of executing the rough classification and details classification using different data. However, the recognition rates of the new approach would be 96% since we need to multiply performance rates of each stage for a hierarchical classification. Hence, we can see that the new approach is efficient and can used in application fields of Korean character recognition.

	recognition rates	
	rough classification	details classification
FONT A	99.6 %	96.8 %
FONT B	99.1 %	95.9 %
FONT C	98.7 %	96.3 %
FONT D	98.2 %	95.2 %
FONT E	99.4 %	95.8 %

Table 2. The experimental results of classification

Conclusions

Korean characters, unlike English letters, are composed of consonants and vowels and have large data set for character recognition. They also have a lot of characters which are similar in shape. Most approaches to Korean character recognition have separated the component letters of Korean characters and have classified these letters. These approaches have difficulties of separating the component letters and have decreased the overall recognition rates.

In this paper, we have proposed a new approach to overcome the disadvantages of using the conventional approaches. The new approach classifies the Korean characters not by their component letters but by whole characters. It uses an ART based neural network hierarchy. To minimize the error in categorization of Korean characters, we have set up variable regions based on the knowledge of different vowel positions. Then we have extracted features which are invariant with respect to various fonts and sizes. These features are selected as training data for an ART1 neural network. First, the training data is classified by features. Then it is again classified details in each category. We have used two different fonts and sizes for the learning phase of the system; and three different fonts in two different sizes for the executing phase. Based upon the results from the executing phase of system, we conclude that the new approach is much more efficient than the approaches where classification of characters by their component letters is used.

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