01 Jan 1995

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Recommended Citation

C. Kim et al., "On-Line Cursive Korean Character Recognition by using Curvature Models," *Proceedings of the 3rd International Conference on Document Analysis and Recognition, 1995*, Institute of Electrical and Electronics Engineers (IEEE), Jan 1995.
The definitive version is available at https://doi.org/10.1109/ICDAR.1995.602086

On-line Cursive Korean Character Recognition by Using Curvature Models

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Abstract

A cursive Korean character consists of several Korean alphabets where connection is present within and among the alphabets. Recognition of Korean characters can be carried out by splitting each character into smaller primitives. Small line segments can be used as the primitives. But this approach requires too much processing time, for there can be many candidate references to be matched to one input character and each reference usually consists of too many primitives.

In this paper, we propose an approach using structural curvature models to overcome the difficulties of using small line segments. These models are obtained by segmenting the input character at the points showing sudden change in direction, excessive rotation, etc.

By doing this, rather larger and structural curve segments can be used as the basic primitives to be matched resulting in the savings of processing time and better recognition rate.

Key words: curvature models, splitting and merging process, on-line cursive character recognition.

1. Introduction

Korean characters, unlike English ones, are structured in a very complex way. That is, a Korean character is a two-dimensional combination of 2 or 3 Korean alphabets - an initial consonant and a vowel, or an initial consonant, a vowel and a final consonant.

Figure 1 (a) is '한글(pronunciation: hangul, meaning: Korean language)' written in a printed style. And (b) is the same word written in a cursive style, so the connection between alphabets is allowed. The first character '한' is a combination of an initial consonant 'ㅎ', a vowel 'ㅏ' and a final consonant 'ㄴ', and the second character is a combination of 'ㄱ', 'ㅡ' and 'ㄹ'.

(a) (b)

Figure 1. An example of a Korean word '한글'

Character recognition approaches can be divided into two groups according to the basic unit of recognition, and the unit is 'stroke' or 'segment'. Feature analysis[1] is a method that utilizes strokes as units of recognition, where DP(dynamic programming)[2], string matching[3], and HMM(hidden Markov modeling)[4] are methods that utilize segments as units of recognition.

Assuming that an input stroke is the basic unit, each stroke can be described precisely using feature analysis approach, but various types of strokes should be registered as references. Assuming that a line segment is the basic unit, any cursive character can be described by combining simple segments, but many primitives is used to construct each character.

Therefore, to describe and recognize cursive characters effectively, 'curvature model', which is similar to the conceptual component of patterns, is proposed as the unit of recognition.

2. Character recognition by using curvature models

2.1 Outline of the recognition process

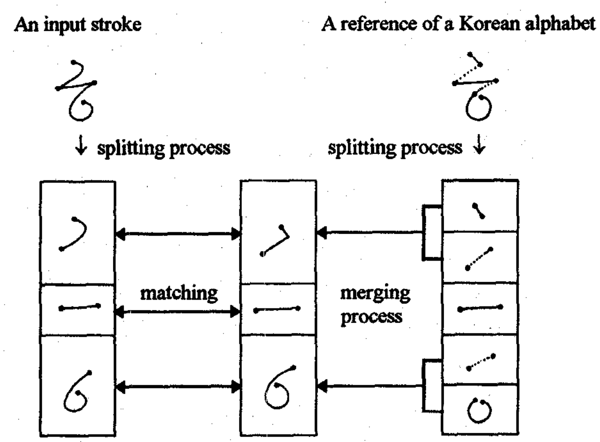


Figure 2. An example of matching using curvature models

The definition of curvature model is a substroke which does not change its direction of rotation. This curvature model is very useful as a basic unit of partitioning and recognizing handwriting patterns. Figure 2 shows how a cursive input pattern of a Korean alphabet 'ㅎ' is partitioned into curvature models, how a reference pattern in a printed style can be described as curvature models, and how they are matched. Here, preprocessing is consisted of distance filtering, angular filtering, and dehooking for extracting key bending points to keep handwritten patterns consistent[5].

2.2 Curvature modeling

To symbolize input and reference patterns as curvature models, splitting and merging steps should be taken. In the splitting stage, all the points that have the possibility of being split within a given stroke are searched. In the merging stage, a curvature model is made by disregarding some of the above points.

2.2.1 Types and descriptions of curvature models: The curvature models are classified into actual components and connecting components. An actual component is the curvature model written with a pen actually, and can be the patterns of straight line, curve, and rotation according to its curvature. A connecting component is the curvature model that connects two actual components and it has two kinds; one is a ligature which is an imaginary line between the previous component and the next component where the pen moves without leaving any trace, and the other is a connecting point which join two continuous actual components.

The sequence of curvature models for a given stroke obtained from the splitting and merging process is represented as follows.

$$\begin{aligned} A &= A_1, A_2, \dots, A_i, \dots, A_n \\ &= (a_{11}, a_{12}, a_{13}), (a_{21}, a_{22}, a_{23}), \dots, \\ &\quad (a_{i1}, a_{i2}, a_{i3}), \dots, (a_{n1}, a_{n2}, a_{n3}) \end{aligned} \tag{1}$$

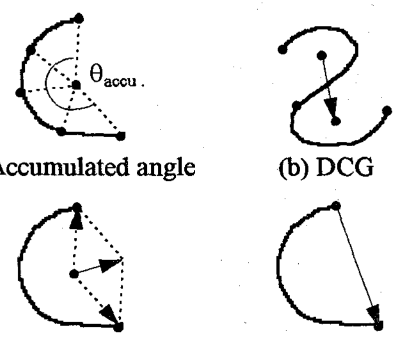
The attributes of a curvature model (a_{i1}, a_{i2}, a_{i3}) have different meanings depending on whether it is an actual component or a connecting component. And table 1 shows the meaning of the attributes.

Table 1. Meaning of the attributes of curvature model

Types / Attributes	Actual component	Connecting component
a_{i1}	Curvature	DCG
a_{i2}	Main direction	Main direction
a_{i3}	DHT	DHT

Descriptions of each of the above terminology are as follows, and are shown in figure 3.

① Curvature: accumulating the angles between vectors toward each point from the center of gravity makes up the accumulated angle; subtracting 180 degrees from the accumulated angle is defined as curvature.
② Main direction: the direction of the sum vector of two vectors toward the head point and the tail point from the center of gravity of a curvature model.
③ DHT(direction from head to tail): the direction of the vector from the head point of a curvature model to the tail point.
④ DCG(direction between centers of gravity): the direction from the center of gravity of the previous curvature model to the center of gravity of the next curvature model which are connected with a connecting component.



(a) Accumulated angle (b) DCG

(c) Main direction (d) DHT

Figure 3. Attributes for describing a curvature model

2.2.2 Splitting: Satisfying at least one of the below conditions, splitting of an input stroke should take place.

① change in rotating direction
② sudden change in direction
③ excessive rotation

As an example, figure 4 shows how the Korean character '호'(pronunciation: ho) is split into four substrokes.

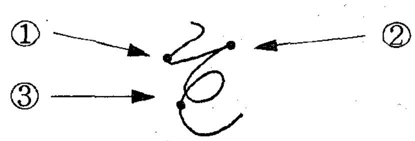


Figure 4. Splitting of a stroke

Here, the point of change in rotating direction is where a clockwise curve meets a counter clockwise curve. The point of sudden change in direction is where a change in direction over 90 degrees occurs. And the point of excessive rotation is where a substroke of circle exceeds 360 degrees.

2.2.3 Merging: All the splitting points searched in the previous stage can be used as reasonable splitting points, but some of these points may be ignored to rejoin a previous curvature model and a next curvature model in the merging stage. The rule of merging is as follows.

① two successive curvature models can be merged, if the change of rotating direction is not occurred when they are joined.

2.3 Matching

Matching is a process that matches the sequence of curvature models of input strokes with the references of Korean alphabets. A reference is also the sequence of curvature models which is made by using the splitting and merging process explained before. But, considering the possibility that an imaginary component might be an actual component, various sequences of reference curvature models are created.

2.3.1 Matching function of curvature models: A linear matching is done between input strokes and Korean alphabet references. The i-th curvature model of an input stroke A_i and the i-th curvature model of a reference B_i are given as equation (2).

$$\begin{aligned} A_i &= (a_{i1}, a_{i2}, a_{i3}) \\ B_i &= (b_{i1}, b_{i2}, b_{i3}) \end{aligned} \qquad (2)$$

Then, the similarity function $F(A_i, B_i)$ that represents the similarity between A_i and B_i is defined as follows.

$$\begin{aligned} F(A_i, B_i) &= 1 - |A_i - B_i| \\ &= 1 - \frac{w_1|a_{i1} - b_{i1}| + w_2|a_{i2} - b_{i2}| + w_3|a_{i3} - b_{i3}|}{180 \cdot (w_1 + w_2 + w_3)} \end{aligned} \qquad (3)$$

Here, the combination of weighting factors w_1, w_2 and w_3 is heuristically decided through experiment when the recognition rate is the highest (actually, $w_1 = 5$, $w_2 = 1$ and $w_3 = 1$), and the difference of each attribute $|a_{ij}-b_{ij}|$ is between 0 and 180. Therefore, the summation of all weighted differences should be divided by $180 \cdot (w_1 + w_2 + w_3)$ to normalize the similarity function $F(A_i, B_i)$ which has a value from 0 to 1. For a curvature candidate whose similarity value is above threshold α, matching is continuously done. If not, no more matching is done.

2.3.2 Recognition of Korean alphabets and a character: When N curvature models make up a Korean alphabet, certainty C of the alphabet is defined as the average for similarity values of N curvature models in equation (4).

$$C = \sum_{i=1}^{N} F(A_i, B_i) \Big/ N \qquad (4)$$

For an alphabet candidate whose certainty is above the threshold β, matching is continuously done. If not, no more matching is done.

As mentioned above, Korean character is different from English character in that a character is composed of 2 or 3 alphabets two-dimensionally. Therefore, type of alphabets and positional relation between them should be considered.

3. Test and result

3.1 Test equipment and data acquisition

The computer used for the test is an IBM PC compatible 486DX(66MHz), and the input device is a WACOM tablet digitizer with a sampling rate of 170 points/sec and a resolution of 510 points/inch.

Data for the test were given by 10 people, 500 different characters for one person considering the frequency of usage and the combination of alphabets in Korean. The survey of Lexicographical Center in Yonsei University is referenced for the frequency of usage in Korean[6]. Cursive style was allowed, and each character was accepted in a 2cm x 2cm box.

3.2 Performance and result

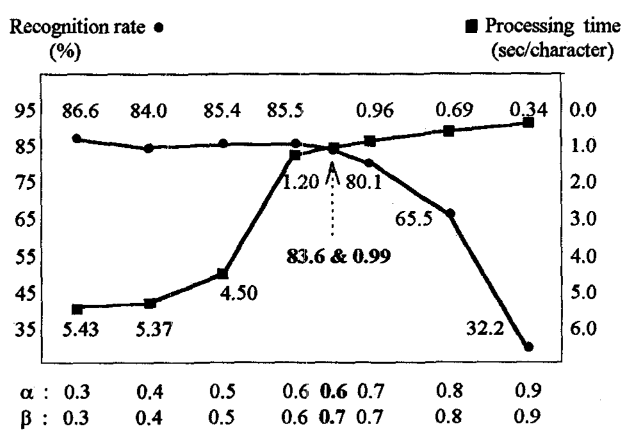


Figure 5. Change of recognition rate and processing time according to the thresholds α and β

Figure 5 shows the measurement of recognition rate and processing time with the change of threshold values α and β. α means the threshold of curvature candidates, and β means that of alphabet candidates whose certainty is the average value for similarity values of several curvature models constructing the alphabet. Therefore, the thresholds α and β satisfy the relation $\alpha \leq \beta$, and have many combinations.

The recognition rate was not tested for all combinations, more simple method was conducted to search the combination of α and β for the highest recognition rate in a given processing time 1sec/character. First, recognition rate was tested for the same values of α and β. As will be seen below, smaller the threshold value the higher the recognition rate. The identical value $\alpha = \beta = 0.7$ was selected for the highest recognition rate in the given processing time. And then, for decreasing values of α recognition rates were tested. Finally, the combination of $\alpha = 0.6$ and $\beta = 0.7$ was selected in the trade-off.

In figure 6, where $\alpha = 0.6$ and $\beta = 0.7$, the recognition rate for the highest 1 candidate is 83.6%, 90.2% for 2 candidates, and so on.

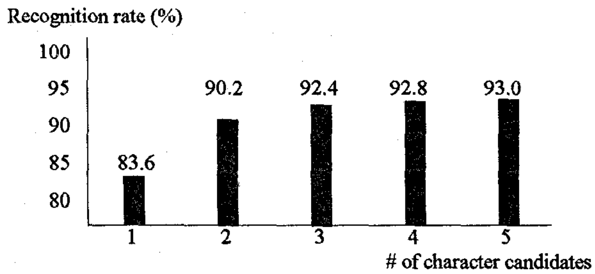


Figure 6. Recognition rates according to the number of character candidates

Figure 7 shows some examples of successful recognition due to good splitting of curvature models.

(a) 상 (b) 김

Figure 7. Examples of successful recognition

One of the main causes for errors is the similarity of Korean characters itself. That is, there are many characters that make it difficult to distinguish each other with an addition of a connecting component. And the biggest factor that affects the recognition time is the candidates that give the same result are maintained. Therefore, it is necessary to delete all the rest of the candidates except one who gives the highest matching value.

4. Conclusion

In the previous research, a stroke or a segment is used as the unit for the recognition of cursive characters. If a stroke is used as a unit of recognition, numerous cursive patterns should be stored. If a segment is used, a large number of primitives would be used to describe a pattern and the matching time would be very long.

Therefore, we propose a recognition method using curvature models which are similar to the conceptual components of patterns, in that a curve is described as a curve itself and a circle is described as a circle itself. This is a more effectively partitioning and describing method than the method using a segment or a stroke as the unit of recognition.

To improve the recognition rate, it is necessary to use additional information related to the splitting and merging process. And a learning method should be used for adding new reference patterns or changing old patterns. Also, just one of intermediate candidates which give identical results should be maintained to reduce the processing time.

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