Reconstructing Handwriting Character Font Models with Incorrect Stroke Order

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ABSTRACT

This paper considers the problem for reconstructing handwriting character fonts based on the so-called dynamic font method. In particular, supposing that the authors are given such character fonts with incorrect stroke order, the authors develop a scheme for correctly modifying the stroke order of characters. Such a scheme is developed by utilizing the so-called starting point fixation method and the dynamic font method. Then it is shown using a theory of smoothing splines that the authors can reconstruct the character fonts to natural cursive characters even when the stroke order of characters is incorrect. The usefulness and effectiveness are examined by experimental studies.

Keywords: Dynamic Font Method, Incorrect Stroke Order, Modified Dynamic Font Method, Reconstructing Characters, Starting Point Fixation Method

INTRODUCTION

Today, displaying documents arises in the wide variety of electronic device, such as personal computer, smart phone, etc. Then various types of characters have been developed and used in such devices. The methods of designing characters are usually classified as (i) dot matrix, (ii) outline vector, and (iii) skeleton vector method, where characters are treated as planer patterns (Sakamoto, 1985; Tokura, 1988; Uehara, 1990).

On the other hand, mimicking the writing process by humans, the so-called “dynamic font method” has been developed by utilizing B-splines (Takayama, 1996). This idea is to introduce a virtual writing device and a virtual writing plane, and then characters are formed as the result of 3-dimensional motion of the writing device. Unlike the conventional methods – such as dot matrix, outline vector and skeleton vector methods, etc., this dynamic font method leads a lot of advantages in the construction and reconstruction of characters (or words and sentences). In particular, one of the advantages is to enable us to readily reconstruct characters to cursive characters as seen in Japanese cal-
The reconstructing scheme has been developed by employing a theory of smoothing splines (de Boor, 1978; Wahba 1990; Kano, 2005). However, such a character reconstruction has been restricted ourselves to the case where the stroke order are correct. Therefore, in such a case, we could not reconstruct the natural cursive characters from characters with incorrect stroke order.

On the other hand, some researheres in the field of on-line character recognization have considered some problems on characters with incorrect stroke order. For example, Wakahara et al. (Wakahara, 1983) have considered a problem of recognizing some character with incorrect stroke order and incorrect stroke number. For solving such a problem, they have developed the so-called “starting point fixation method” using DP matching. However, this method is only for pattern recognition of characters, thus does not intend to modify the incorrect stroke order.

In this study, we consider the problem for reconstructing handwriting characters, where we suppose that a stroke order of characters may be incorrect. Using the modified dynamic font method, the handwriting character is modeled by employing a theory of smoothing splines. In particular, supposing that character is generated by human arm motion (Edelman, 1987; Wada, 1985; Morasso, 1982; Plamondon, 1998; Latash, 2003), we introduce a smoothing spline theory based on minimum hand jerk model (Flash, 1985). The handwriting motion is developed as a circular cone moving in a 3-dimensional space O-XYZ. The virtual writing plane is defined as 2-dimensional plane O-XY. Then, characters are generated by moving the writing device in O-XYZ according to the writing motions designed for each l-th stroke and then by deriving the cross-sectional area on the writing plane. Note here that a difference between this method and original method in the reference (Takayama, 1996) is on a point if we do or not suppose continuities in time and space for whole writing motion corresponding to characters Ch.

Letting be a writing motion of writing device, say a tip of writing device. Then such a trajectory is designed by using quintic B-splines as the basis functions:

\[
x(t) = [X(t) Y(t) Z(t)]^T
\]  

(1)

Let be a writing motion of writing device, say a tip of writing device. Then such a trajectory is designed by using quintic B-splines as the basis functions:

\[
\]

We examined the usefulness and effectiveness of proposed scheme by experimental studies.

### MODELING HANDWRITING CHARACTERS USING DYNAMIC FONT METHOD

Based on the dynamic font method (Takayama, 1996), we develop a method for constructing handwriting characters Ch with stroke orders from human handwriting motion data. First, we briefly present a modified dynamic font method. Then, we present how to model characters from human handwriting motion data.

### Modified Dynamic Font Method

As shown in Figure 1, we here consider a virtual writing device and a virtual writing plane. The virtual writing device is modelled as a circular cone moving in a 3-dimensional space O-XYZ. The virtual writing plane is defined as 2-dimensional plane O-XY. Then, characters Ch are generated by moving the writing device in O-XYZ according to the writing motions designed for each l-th stroke and then by deriving the cross-sectional area on the writing plane. Note here that a difference between this method and original method in the reference (Takayama, 1996) is on a point if we do or not suppose continuities in time and space for whole writing motion corresponding to characters Ch.

Letting be a writing motion of writing device, say a tip of writing device:

\[
x_i(t) = [X_i(t) Y_i(t) Z_i(t)]^T
\]  

(1)

Let be a writing motion of writing device, say a tip of writing device. Then such a trajectory is designed by using quintic B-splines as the basis functions:
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