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## **Trajectory generation of the writing-brush for a robot arm to inherit block-style Chinese character calligraphy techniques**

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**Abstract**—This paper relates the trajectory generation of the writing-brush for a robot arm to inherit Chinese character calligraphy (CCC) techniques. First, to preserve the characters written by famous calligraphers in Chinese history, we constructed a CCC database which contains 29 456 characters written by different calligraphers in different styles (ancient, angular, block, semi-cursive and cursive style). With this CCC database, it is possible to search, restore and append the calligraphy writing for a specific character. Second, we mainly relate the inheritance of CCC. Because CCC is not a static thing, but a dynamic process of an activity which concerns a lot of complicated factors such as the pressure and speed control of the writing brush, how to write the start and end of strokes, etc., we propose to inherit this dynamic process by a robot. This paper is limited to discussing how to inherit the writing techniques for block-style calligraphy writing by a robot arm. The total number of Chinese characters is more than 800 000. These characters can be constructed by basic strokes. There are 28 different kinds of strokes used to construct all of these characters. The skeleton of a stroke is decided by the control points that exist within the stroke. The shape of a stroke is determined by the trajectory derived from the control points and the pressure to the writing brush. The control points for 28 strokes are given and the control techniques for a robot to write these strokes in block style are developed. At present, the robot can write any character in block style.

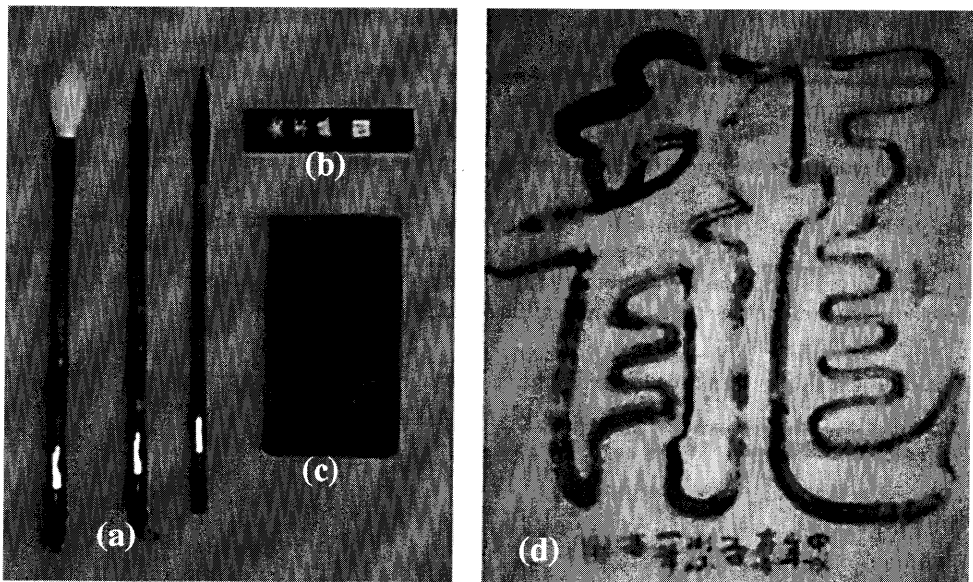
*Keywords:* Chinese character calligraphy; character image pattern; thinning; trajectory generation; B-spline.

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



























## 1. INTRODUCTION

The Chinese character calligraphy (CCC) culture has more than 4000 years of history. Chinese characters are divided into six categories: pictographic characters, pictophonetic characters, associative compound characters, self-explanatory characters, phonetic loan characters and synonymous characters. These characters are constructed by strokes. There are 28 strokes used to construct all of the characters. Table 1 shows their image patterns and names. To make the description easy, these strokes are coded from  $S_0$  to  $S_{27}$ , i.e. the strokes are denoted by a set  $S = \{S_0, \dots, S_{27}\}$ , where strokes  $S_{20}$  and  $S_{27}$  are used only to constructed simplified Chinese characters. CCC expresses these characters by using a writing brush, Chinese ink, paper and a stone slab, which are called the 'four treasures for study'. Figure 1a–d shows three writing brushes, a piece of Chinese ink, a stone slab, and a piece of artwork of a character for 'dragon' written by using the writing brush and Chinese ink, respectively. Although the writing brush in CCC is similar to the brush used for watercolor painting in the West, it has a finer tip suitable for dealing with a wide range of subjects and for producing the variations in line required by different styles. Since the materials used for CCC and Chinese painting are essentially the same, developments in calligraphic styles and techniques can also be used in Chinese painting. Chinese ink has been used in CCC and Chinese painting for over 2000 years. When the ink cake is ground on the painter's stone slab with fresh water, inks of various consistencies can be prepared depending on the amount of water used. Thick ink is very deep and glossy when applied to paper or silk. Thin ink



**Figure 1.** (a) Writing brush. (b) Chinese ink. (c) Stone slab. (d) An artwork of a character for 'dragon' written by using the writing brush and Chinese ink.

**Table 1.**  
Stroke patterns used construct Chinese characters

Code	Pattern	Stroke name	Code	Pattern	Stroke name
S <sub>0</sub>		dot stroke	S <sub>14</sub>		horizontal and fold stroke
S <sub>1</sub>		horizontal stroke	S <sub>15</sub>		horizontal, fold and hook stroke
S <sub>2</sub>		vertical stroke	S <sub>16</sub>		horizontal and left-falling stroke
S <sub>3</sub>		left falling stroke	S <sub>17</sub>		left-falling and fold stroke
S <sub>4</sub>		right falling stroke	S <sub>18</sub>		left-falling and dot stroke
S <sub>5</sub>		rising stroke	S <sub>19</sub>		vertical and fold stroke
S <sub>6</sub>		vertical and hook stroke	S <sub>20</sub>		horizontal, fold and rising stroke
S <sub>7</sub>		curved hook stroke	S <sub>21</sub>		horizontal, fold and curved-hook stroke
S <sub>8</sub>		inclined hook stroke	S <sub>22</sub>		vertical, fold and curved-hook stroke
S <sub>9</sub>		lying hook stroke	S <sub>23</sub>		horizontal, fold, fold and left-falling stroke
S <sub>10</sub>		vertical and turn-right stroke	S <sub>24</sub>		horizontal, left-falling and curved-hook stroke
S <sub>11</sub>		vertical, turn-right and hook stroke	S <sub>25</sub>		horizontal, fold, fold and curved-hook stroke
S <sub>12</sub>		vertical and rising stroke	S <sub>26</sub>		horizontal, fold and turn-right stroke
S <sub>13</sub>		horizontal and hook stroke	S <sub>27</sub>		horizontal, fold and left-falling stroke

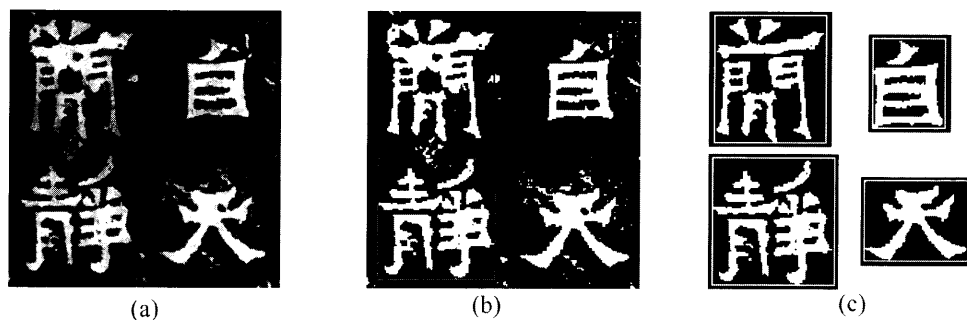
appears lively and translucent. As a result, in ink-and-wash paintings it is possible to use ink alone to create a rhythmic balance between brightness and darkness, and density and lightness, and to create an impression of the subject's texture, weight and coloring. CCC and Chinese painting may be done either on Chinese paper or silk. The paper is very absorbent and the size of it will dictate the quantity of ink used for strokes on the paper. Different paper produces different results; some are rough and absorb ink quickly like a sponge, others have a smooth surface which resists ink. Chinese paper is usually known as rice paper in English. Silk is less absorbent than paper. The brushstroke is best shown on paper. For this reason and the variety of texture and finish of paper, the paper is favored by artists and calligraphers. The calligraphers in Chinese history created and developed a variety of writing styles to write characters by using writing brushes. These styles can be



**Figure 2.** Five different writings of the Chinese character for ‘wind’. (a) Ancient. (b) Angular. (c) Block. (d) Semi-cursive. (e) Cursive.

roughly categorized into (i) ancient, (ii) angular, (iii) block, (iv) semi-cursive and (v) cursive styles. Figure 2 shows five different writing examples of the Chinese character for ‘wind’. The ancient style as shown in Fig. 2a employs thin curved lines to express strokes. The ends of these thin curved lines are sharp and the lines are vigorous. This style prospered in the Qin Dynasty (221–207 BC). The angular style was invented by Chengmao — a prison officer in the Qin Dynasty — to deal with complicated official documents rapidly. In this style, as shown in Fig. 2b, the horizontal strokes are written horizontally and the vertical strokes vertically, and the combinations among strokes are emphasized. The angular style is much easier to write than the ancient style. The block style was developed in the Han Dynasty (206 BC to AD 220). It is an improved style based on the angular style. The block style is, again, easier to write than the angular style. This style was prominent in the Tang Dynasty (618–907). The semi-cursive style lies between the block style and the cursive style. In the semi-cursive style, as shown in Fig. 2d, the corners are not as squarish as in the angular style and not as round as in the ancient style. This style is a variation of the block style. In the cursive style, as shown in Fig. 2e, the structure is simple and there is no break in the movement track of the writing brush. It enables one to write quickly. There are many variations of the cursive style and there are many artworks written in this style. The CCC culture was also imported by Japan, Korea and south-east Asian countries, developed in its own way in these countries and became part of the cultures of these countries.

However, since the ‘hard’ writing tools such as the pencil, pen and ball-pen were introduced into these countries, more and more people have put away the writing brushes, and used pencils and pens. In most schools, students are being taught to write only using pencils. Even for those schools which teach students to write with writing brushes, the amount of time spent on the subject is very small in comparison with other subjects. This situation has lasted for more than a half of a century. Therefore, generally speaking today, young people in China, Japan, Korea, etc., cannot write characters with writing brushes except for those people who have received special training to write the characters by brushes. Furthermore, with the spread of the computer word processors, such as Word, Ichitaro, etc., more and more people get used to using them and do not like to write characters even using a pen or pencil, not to mention the writing brush. Therefore, the number of



**Figure 3.** (a) A piece of rubbed copy including four characters. (b) Extracted characters. (c) Restored characters registered in the CPD.

competent calligraphers is decreasing day by day. If this situation continues for several decades, CCC culture may face extinction.

The purpose of this work is to preserve and inherit CCC culture by a robot. The whole work consists of three steps. The first step is to preserve the characters written by famous calligraphers in Chinese history. This is because many famous CCC artworks were written on planks or engraved on stone tablets, and many of them are not in a complete state after several thousands of years. Although many of them were made as rubbed copies, the copies are not in a good state. Figure 3a shows a piece of rubbed copy from a stone tablet which contains four characters. It is difficult to restore these characters on paper copies. Here, we input them into the computer and construct a CCC database. This makes it easier to search and restore the CCC artworks on computer. The second step is to inherit the CCC techniques by a CCC robot [1]. CCC not only means the static artwork, but also the dynamic process of producing the artwork, which contains the control and movement of the writing brush. This dynamic processing contains a lot of techniques such as pressure control, speed control, turn control, etc. These aspects are very difficult to master and imitate even though people may know the principles or rules to write by writing brushes because there exists a big gap between CCC theory and practice, and because the top of the writing brush is very soft. The hand and arm of a person may not move as precise as one images, but the robot arm can. Thus, we propose to employ the robot arm to inherit the CCC techniques. The third step is to let the robot teach CCC techniques to the human being. In this way the robot can preserve and inherit the CCC culture. We constructed the prototype system for the first two steps. This paper is limited to describing the CCC database construction in the first step and how to inherit the block-style calligraphy writings in the second step. The remainder of this paper is organized as follows. Section 2 describes the preservation of the CCC artworks. Section 3 relates the inheritance of CCC techniques for block-style calligraphy writings by a robot. Section 4 presents the experiment results. The paper finishes with conclusions and remarks.