# Automatic Shape Morphing for Chinese Characters

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## Abstract

How to automatically implement shape morphing for Chinese characters represented in different styles is a challenging task. In this paper, we propose a novel method to solve this problem. Specifically, we first generate the shape template, which includes a skeleton, strokes, key points, and connection triangles, for every character in a standard Chinese font (i.e., Kaiti) library. Then, we decompose two given Chinese characters into strokes to establish an accurate correspondence between them by applying the Coherent Point Drift (CPD) algorithm to achieve non-rigid point set registration between each character and the corresponding template. Finally, we construct an isomorphic triangulation for the source and target character shapes, and then apply as-rigid-as-possible shape interpolation on these two triangle meshes. Experimental results demonstrate the effectiveness of our method.

**CR Categories:** I.3.5 [Computer Graphics]: Computational Geometry and Object Modeling—Curve, surface, solid, and object representations

Keywords: shape morphing, Chinese characters, correspondence

## 1 Introduction

Shape morphing techniques, which transform a source shape into a target shape smoothly, have been widely used in recent years. The morphing process typically consists of the following two key steps: 1) correspondence finding [Liu et al. 2004] [Yang and Feng 2009] [Belongie et al. 2002], which aims to establish a correspondence between the source and target shapes; 2) path interpolation [Alexa et al. 2000] [Schaefer et al. 2006], which interpolates the positions of two shapes along predetermined paths to compute the positions of intermediate shapes. Now, how to automatically establish accurate correspondence and generate smooth path interpolation between two shapes is still considered to be a challenging problem in many applications. One tough task among them is the automatic shape morphing for Chinese characters with various styles (see Figure 1). The technique can be utilized to significantly enhance the efficiency in generating animations [Xu et al. 2006] [Schaefer et al. 2006], computer calligraphy [Xu et al. 2005], and Chinese font libraries [Zhou et al. 2011]. In order to get satisfactory morphing results, existing methods need to manually specify all corresponding points on two shapes. This is mainly due to the complexity of Chinese character shapes (see Figure 1 for exam-

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**Figure 1:** *Results of our automatic shape morphing method for a Chinese character represented in five different styles.* 

ples). On the one hand, a Chinese character might contain dozens of various kinds of strokes. On the other hand, the topological structure of the character and the appearances of strokes might also be quite different when the character is written or designed in different styles. As we know, there are totally more than a hundred thousands of Chinese characters available and the most popular official character set GB2312 includes 6763 simplified Chinese characters. Assume that we want to use existing shape morphing techniques to create new font libraries based on two given Chinese fonts under the GB2312 national standard, then we have to manually specify the precise positions of all corresponding points between 6763 pairs of characters represented in two different font styles. Moreover, existing methods, which are typically developed for simple shapes (e.g., a single polygon), are not able to generate smooth and natural morphing results for many complicated Chinese characters. Thereby, those existing approaches are not well suited for practical uses and there exist increasing demands in the development of fully automatic shape morphing techniques for Chinese characters.

Up to now, large amounts of methods have been proposed for shape morphing. One of the most famous approach is the as-rigid-aspossible shape interpolation algorithm [Alexa et al. 2000], which blends the interiors of given shapes rather than their boundaries to establish global coherent least-distorting transformations during the morphing process. Other techniques such as Moving Least Squares [Schaefer et al. 2006], Poisson Interpolation [Xu et al. 2006], and so on have also been applied to achieve smooth shape morphing. However, these papers all concentrate on the path interpolation process and they either assume the predetermined correspondence between two shapes or should establish the correspondence in a semiautomatic way. As mentioned above, it is helpful and sometimes even necessary to automatically specify accurate positions of all corresponding points in many applications. Matching local features (e.g., Shape Contexts [Belongie et al. 2002]) extracted from two shapes is an intuitive choice to solve the correspondence problem. Liu et al. [Liu et al. 2004] used a local feature that involves the computations of the convexity and the tangent direction on the feature point to measure the similarity between two points, and applied the dynamic programming graph to find the optimal correspondence. Yang and Feng [Yang and Feng 2009] utilized the visual appearance, orientation and relative size of 2D shapes to optimally associate the feature points on the source shape with the corresponding ones on the target shape. Those existing methods work fairly well for some shapes that can be represented as a single polygon, but they are not guarantied to establish correct

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correspondence for all kinds of shapes, especially for complicated objects consisting of multiple disconnected components (e.g., some Chinese characters). Another potential solution is the point set registration technique that aims to assign correspondences between two given point sets, one of which can be mapped to the other under a rigid or non-rigid transformation. The most prominent tool for rigid point set registration is the Iterative Closest Point (ICP) method [Zhang 1994], and the Coherent Point Drift (CPD) algorithm recently proposed in [Myronenko and Song 2010] is one of the best-known approaches to register non-rigid point sets. Unfortunately, our experiments show that the point set registration technique can not be directly applied in our case since the transformation that maps a whole Chinese character in one style to another is too complicated to recover. Yet, there already exist some work specifically aiming at shape morphing for Chinese characters. For instance, Pan et al. [Pan et al. 1997] utilized an algebraic system of geometric shapes based on the Fourier descriptor, while Liu et al. [Liu et al. 1999] developed a morphology based method by constructing the mapping between convex subsets of two given characters using general optimization relax iteration. More recently, Xu et al. [Xu et al. 2005] presented an intelligent system to generate artistic Chinese calligraphy by a skeleton-based shape interpolation of given characters. However, existing methods are either required extensive user labor or poor in performance.

In this paper, a novel approach is proposed to effectively address the challenging problem of automatic shape morphing for Chinese characters. The key idea is to decompose each character into strokes to establish an accurate correspondence between two given shapes using a non-rigid point set registration method, and then carry out as-rigid-as-possible shape interpolation between them. In this manner, as shown in Figure 1, our method not only can automatically implement shape morphing between Chinese characters in different styles, but also can obtain smooth and natural morphing results that correspond reasonably well with human intuition.

## 2 Method Description

In this section, we first present an overview of our method and then elaborate on the details of each step. As shown in Figure 2, our method consists of the following three steps:

- 1. *Template Construction:* Build the shape template that consists of a skeleton, strokes, key points, and connection triangles for every Chinese character in the standard Kaiti font library via a user interface we developed. Note that we only need to implement this step once.
- 2. *Correspondence Finding:* Extract strokes from two given characters and then establish a correspondence between them based on the non-rigid point set registration between each shape and the character's template.
- 3. *Shape Interpolation:* Construct a compatible triangulation for these two shapes, and then transform the source triangle mesh to the target one smoothly by applying the as-rigid-aspossible shape interpolation algorithm.

#### 2.1 Template Construction

As mentioned above, shapes of many Chinese characters are extremely complicated, which makes the correspondence finding and path interpolation problems nontrivial. Fortunately, they are also specially-constructed shapes, which can be decomposed into a set of strokes, and a given character represented in different styles consists of the same kinds of strokes. Building the template, which contains a skeleton, strokes, and other valuable information, for ev-



Figure 2: Overview of our method.

ery character in a selected font library to exploit those special properties of Chinese characters can be quite helpful to establish correspondence correctly and to blend shapes naturally. In this paper, we construct templates for all Chinese characters in the standard Kaiti font library. The template consists of four components as follows:

*Strokes.* As we can see from the first block in Figure 2, strokes are perfectly extracted for each reference character and even the hidden parts of strokes are also completely recovered. The work of stroke extraction for every Chinese character in the GB2312 Kaiti font library has been done manually by a company called Founder Group. Here, we directly use the data they generated.



Figure 3: Specifying the skeleton and key points on the contour for a given Chinese character through a user interface we developed.

*A skeleton.* The skeleton is used for the registration between the reference character and the corresponding character to be processed. To get better performance, we manually specify the skeleton for the reference character through a user interface (see the first row in Figure 3) rather than automatically generate it by algorithms.

*Key points.* We first select salient points on the contour for every stroke of the reference character via a user interface we developed (see the second row in Figure 3). Then, we evenly sample a number

(e.g., seven) of points on the contour between every two key points. Finally, every stroke can be approximated by a polygon consisting of those sampled points and key points.

**Connection triangles.** Since the shape interpolation algorithm applied in our method can not handle shapes with disconnected components, we manually generate a set of invisible triangles to link all strokes into a combined object. Experiments demonstrate that our morphing results are considerably insensitive against the selection of connection triangles.

### 2.2 Correspondence Finding



Figure 4: A demonstration of our stroke extraction approach.

Establishing accurate correspondence is a critical step to obtain high-quality shape morphing results and how to automatically achieve this goal is still an unsolved problem in many applications. Especially for the task of automatic shape morphing for Chinese characters, the morphing result will be greatly distorted and the generated character might even be unrecognizable if there exist incorrect correspondences between some salient points on the contours. In this paper, we develop a simple and intuitive approach to effectively address this problem. The basic strategy is to decompose the challenging task into the following two easier problems:

**1. Stroke Extraction:** As shown in Figure 4, given a Chinese character (e.g., in the Heti style), we first extract its skeleton using the classic thinning algorithm. Then, we apply the Coherent Point Drift (CPD) algorithm [Myronenko and Song 2010] to register the point set (e.g., 400 points) randomly sampled from the character's skeleton (lower one in the figure) to the skeleton template extracted from the corresponding reference character (upper one) in the first step. Afterwards, we segment the skeleton of the character into skeletons of strokes based on the non-rigid registration result. Finally, by assigning points on the contour to the closest points on the skeleton, completing and smoothing segmented contours, we accurately decompose the given Chinese character into several strokes.



**Figure 5:** *Registering a given stroke to the corresponding stroke template to establish a correspondence between them.* 

**2.** *Stroke Registration:* Due to the complexity of Chinese characters, it is often impossible to completely register the whole contour of a given character to another. However, the registration of two strokes is much easier. As shown in Figure 5, we utilize the CPD algorithm again to register the contour of each stroke of the given character to the point set of the corresponding stroke template. Based on the result of non-rigid point set registration, corresponding key points on each stroke are obtained. Then by evenly sampling (e.g., 7 points) contours between every two key points and detecting corner points [He and Yung 2008], we obtain other corresponding points on the contours of strokes to be processed.

#### 2.3 Shape Interpolation



Figure 6: The triangulation of a given character.

In this step, we first construct an isomorphic triangulation for two given characters based on the correspondence established above. Then we apply the as-rigid-as-possible shape interpolation algorithm [Alexa et al. 2000] to transform the source triangle mesh to the target one smoothly.

As shown in Figure 6, given the source character and its strokes, we apply the Delaunay triangulation method to triangulate the polygon of each stroke. Final triangle mesh of the whole character is obtained by linking all strokes together into a combined shape via the connection triangles generated in the first step. Applying the same triangulation as the source shape to the target one, we get the target character's triangle mesh that is isomorphic to the source one.

The shape interpolation problem in our method can be stated as follows: Given the source 2D mesh M which consists of  $N_t$  triangles  $\{T_1, T_2, \ldots, T_{N_t}\}$  and  $N_v$  vertices  $\{V_1, V_2, \ldots, V_{N_v}\}$ , we would like to smoothly transform M to the target 2D mesh  $\tilde{M}$  that is composed of  $N_t$  triangles  $\{\tilde{T}_1, \tilde{T}_2, \ldots, \tilde{T}_{N_t}\}$  and  $N_v$  vertices  $\{\tilde{V}_1, \tilde{V}_2, \ldots, \tilde{V}_{N_v}\}$ . In other words, we need to construct the intermediate mesh  $\tilde{M}(t)$  containing  $N_t$  triangles  $\{\tilde{T}_1(t), \tilde{T}_2(t), \ldots, \tilde{T}_{N_t}(t)\}$  and  $N_v$  vertices  $\{\tilde{V}_1(t), \tilde{V}_2(t), \ldots, \tilde{V}_{N_v}(t)\}$ , where  $t \in [0, 1]$ , based on the interpolation of M and  $\tilde{M}$ . Let the vertices of the source triangle  $T_i$  and the target triangle  $\tilde{T}_i$  be  $\{V_{i_1}, V_{i_2}, V_{i_3}\}$  and  $\{\tilde{V}_{i_1}, \tilde{V}_{i_2}, \tilde{V}_{i_3}\}$ , respectively, we have

$$A_i V_f + L_i = \begin{bmatrix} a_{i1} & a_{i2} \\ a_{i3} & a_{i4} \end{bmatrix} \begin{bmatrix} x_f \\ y_f \end{bmatrix} + \begin{bmatrix} lx_i \\ ly_i \end{bmatrix} = \tilde{V}_f, \quad (1)$$

where  $\tilde{V}_f = [\tilde{x}_f, \tilde{y}_f]^T$ ,  $f \in \{i_1, i_2, i_3\}$ . Based on the Singular Value Decomposition (SVD), the transformation factor  $A_i$  can be decomposed into a single rotation and a symmetric matrix by

$$A_{i} = R_{i}(\alpha)D_{i}R_{i}(\beta) = (R_{i}(\alpha)R_{i}(\beta))(R_{i}^{T}(\beta)D_{i}R_{i}(\beta))$$
  
=  $R_{i}(\gamma)S_{i}.$  (2)

Then, by linearly interpolating the free parameters in Eq. 2 we get

$$A_{i}(t) = \begin{bmatrix} a_{i1}(t) & a_{i2}(t) \\ a_{i3}(t) & a_{i4}(t) \end{bmatrix} = R_{i}(t\gamma)((1-t)I + tS_{i}).$$
(3)

Let the vertices of the intermediate triangle  $T_i(t)$  be  $\{\tilde{V}_{i_1}(t), \tilde{V}_{i_2}(t), \tilde{V}_{i_3}(t)\}$  and the matrix for the affine transformation from  $T_i$  to  $\tilde{T}_i(t)$  be  $\tilde{A}_i(t)$ , we have

$$\tilde{A}_{i}(t)V_{f} + \tilde{L}_{i}(t) = \tilde{V}_{f}(t), f \in \{i_{1}, i_{2}, i_{3}\}.$$
(4)

Locations of those triangles on mesh  $\tilde{M}(t)$  can be determined by minimizing the quadratic error between the actual matrix  $A_i(t)$  and the desired one  $\tilde{A}_i(t)$ . We write the minimization problem as

$$\min_{\tilde{V}_1(t),...,\tilde{V}_{N_v}(t)} \sum_{i=1}^{N_t} \left\| A_i(t) - \tilde{A}_i(t) \right\|^2.$$
(5)

To have a unique solution for Eq. (5), a vertex, say  $\tilde{V}_1(t)$ , is considered as a constant rather than as a free variable. By setting  $\tilde{U}^T(t) =$ 



Figure 7: Automatic shape morphing results obtained using our method for several Chinese characters with different styles.



Figure 8: Automatic shape morphing results for a character by directly applying the CPD approach on the whole shape. Underneath are the number of iterations. Red cross means that the method is not able to completely transform the source shape to the target one.

 $[\tilde{x}_2(t), \tilde{y}_2(t), \dots, \tilde{x}_{N_v}(t), \tilde{y}_{N_v}(t)]$  and  $C^T = [\mathbf{c}_1(t), \dots, \mathbf{c}_{N_t}(t)]$ where  $\mathbf{c}_i(t) = [a_{i1}(t), a_{i2}(t), a_{i3}(t), a_{i4}(t)]$ , the minimization problem (Eq. (5)) can be rewritten as

$$\min_{\tilde{x}_{2}(t), \tilde{y}_{2}(t), \dots, \tilde{x}_{N_{v}}(t), \tilde{y}_{N_{v}}(t)} \left\| C - H\tilde{U}(t) \right\|^{2}, \tag{6}$$

in which H is a sparse matrix that relates  $\tilde{U}(t)$  to C, and the elements of H can be easily computed based on Eq. (4). We solve the minimization problem by setting the gradient of the objective function over the free variable  $\tilde{U}(t)$  to zero:  $H^T H \tilde{U}(t) = H^T C$ , on which we apply a sparse QR solver to calculate  $\tilde{U}(t)$ .

### 3 Results

To validate the effectiveness of our method, we carried out experiments on five Chinese font libraries (i.e., Kaiti, Fangsong, Lishu, Heiti, and a handwriting style). The algorithm was implemented in Matlab R2010a under Windows 7 on a laptop with a 2.30GHz Intel Core i5 CPU and 3.0GB DDR2 memory. Parameters of our method are selected as follows: the resolution of character images is about 350x350, the number of iterations for the CPD algorithm is 50, and the number of intermediate shapes generated in one morphing process is 20. On average, it takes about 60 seconds to manually build a template, 200 seconds to automatically establish the correspondence between two shapes, and 10 seconds to finish the shape interpolation step.

Figure 1 shows some morphing results obtained using our method for a Chinese character in aforementioned five styles. As we can see, with a template constructed off-line we can automatically transform a source character in one style to a target character in any other styles smoothly and naturally. Figure 7 again demonstrates the effectiveness of our method by showing the automatic shape morphing results for some other Chinese characters, which correspond quite well with human intuition. Finally, we compare our method with another automatic shape morphing approach that directly applies the CPD algorithm [Myronenko and Song 2010] on the contours of whole characters. As we can see from Figure 8, the method generates unsatisfactory intermediate shapes and, more importantly, it is not able to completely transform the source shape into the target one. Obviously, our method performs much better.

## 4 Conclusion

In this paper, we present an automatic shape morphing method for Chinese characters represented in various styles, addressing tough problems including how to establish an accurate correspondence between two characters and how to achieve natural morphing for complicated shapes that consists of disconnected multiple components. However, some limitations also exist in our method: 1) the correspondence finding step based on non-rigid point set registration is computationally expensive; 2) our method is not able to generate satisfactory morphing results for some cursive handwriting characters. We will try to solve these problems in the future.

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### References

- ALEXA, M., COHEN-OR, D., AND LEVIN, D. 2000. As-rigid-aspossible shape interpolation. In *Proc. ACM SIGGRAPH 2000*.
- BELONGIE, S., MALIK, J., AND PUZICHA, J. 2002. Shape matching and object recognition using shape contexts. *IEEE Trans. PAMI* 24, 4, 509–522.
- HE, X., AND YUNG, N. 2008. Corner detector based on global and local curvature properties. *Optical Engineering* 47, 5, 057008.
- LIU, W., WAN, F., AND ZHU, G. 1999. A novel method of chinese font composition based on morphology. *Chinese Journal of Computers* 22, 3, 235–240.
- LIU, L., WANG, G., ZHANG, B., GUO, B., AND SHUM, H. 2004. Perceptually based approach for planar shape morphing. In *Proc. PG'04*, 111–120.
- MYRONENKO, A., AND SONG, X. 2010. Point set registration: Coherent point drift. *IEEE Trans. PAMI* 32, 12, 2262–2275.
- PAN, Z., MA, X., ZHANG, M., AND SHI, J. 1997. Chinese font composition method based on algebraic system of geometric shapes. *Computer & Graphics* 21, 3, 321–328.
- SCHAEFER, S., MCPHAIL, T., AND WARREN, J. 2006. Image deformation using moving least squares. In *Proc. ACM SIG-GRAPH 2006*, 533–540.
- XU, S., LAU, F., CHEUNG, W., AND PAN, Y. 2005. Automatic generation of artistic chinese calligraphy. *IEEE Intelligent Systems* 20, 3, 32–39.
- XU, D., ZHANG, H., WANG, Q., AND BAO, H. 2006. Poisson shape interpolation. *Graphical Models* 68, 3, 268–281.
- YANG, W., AND FENG, J. 2009. 2d shape morphing via automatic feature matching and hierarchical interpolation. *Computer & Graphics 33*, 3, 414–423.
- ZHANG, Z. 1994. Iterative point matching for registration of freeform curves and surfaces. *IJCV 13*, 2, 119–152.
- ZHOU, B., WANG, W., AND CHEN, Z. 2011. Easy generation of personal chinese handwritten fonts. In *Proc. ICME'04*, 1–6.