Semi-automatic Field Morphing : Polygon-based Vertex Selection and Adaptive Control Line Mapping

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ABSTRACT

Image morphing deals with the metamorphosis of one image into another. The field morphing depends on the manual work for most of the process, where a user has to designate the control lines. It takes time and requires skills to have fine quality results. It is an object of this paper to propose a method capable of realizing the semi-automation of field morphing using adaptive vertex correspondence based on image segmentation. The adaptive vertex correspondence process efficiently generates a pair of control lines by adaptively selecting reference partial contours based on the number of vertices that are included in the partial contour of the source morphing object and in the partial contour of the destination morphing object, in the pair of the partial contour designated by external control points through user input. The proposed method generates visually fluid morphs and warps with an easy-to-use interface. According to the proposed method, a user can shorten the time to set control lines and even an unskilled user can obtain natural morphing results as he or she designates a small number of external control points.

1. INTRODUCTION

George Wolberg [1] defines image warping as the field that handles the geometric metamorphosis of a given image. The geometric metamorphosis of an image is to reconstruct the spatial relations among each pixel in the image. Making a sequential transformation between two images is referred to as image morphing. With the exception of the fact that warping does not have the intermediary process between two images, warping and morphing are almost the same works. While warping is unary operation, morphing is binary operation [2].

T. Beier and S. Neely define multiple control lines that represent respective features well from a source image and a destination image. They visualize the image morphing by calculating mathematically how the pairs of each of the control lines are changed and matched, moving surrounding pixels, and interpolating them [3].

Though image warping has been around for decades, it has become very popular in the last years. In its beginning, it was used by NASA to straighten images received by satellites and space missions. These images appeared to be captured through a fisheye lens, and by processing these images with computers, camera aberrations were removed. Films like *Terminator 2* and *Mask* used image morphing to transform humans into metallic humanoids and living caricatures. Just a few years ago, morphing cost upwards of hundreds of thousands of dollars to

generate a few minutes of film on high-priced workstations.

Today, inexpensive commercial software packages and even shareware allow you to perform these techniques on your computer. Now, techniques that were once limited to scientists at NASA are present in video games, television commercials, and music videos. Image warping algorithm can be classified in accordance with the method designated for the features of modified part, and the representative ones are field warping and mesh warping. Mesh warping is to carry out the geometric warping in mesh unit after dividing the source image and the destination image into a multiple number of polygons that are mutually corresponding. The field warping is easier to set the control line than the mesh warping, and relatively less sensitive to the change of position or length of the control line [4].

The field warping can have various warping result depending on the control line designated by the user. In order to obtain the high quality of image result, accurate control lines have to be designated. Such control lines are inputted by manual work that it requires many work time and needs high level of skill to earn a high quality of outcome. In this paper, a proposal is made to realize the semi-automation of field image warping and morphing by using the image segmentation technology in a way to resolve such difficulties partially. This paper presents a semi-automatic field morphing using adaptive vertex correspondence based on image segmentation that can efficiently generate a pair of control lines by adaptively selecting reference partial contours based on the number of vertices that are included in the partial contour of the source morphing object and in the partial contour of the destination morphing object, in the pair of the partial contour designated by

external control points through user input

2. IMAGEMENTAMORPHOSIS

2.1 Image Morphing

Image morphing sometimes referred to as "image interpolation in the time domain," deals with the metamorphosis or one image to another [5]. It is a technique widely used in television commercials,

music videos and motion pictures. Image morphing has also been used for facial recognition [6]. Given a pair of images, the goal of image morphing is to find a sequence of intermediate images, such that the first image in the sequence is equal to the first given image (source image) and the last image is equal to the second given image (destination image). The process begins with finding a reasonable warping function between the two images, and this warping function is then used to interpolate the position of pixels through the in-between sequence. Finally, intensity or color interpolation (i.e., cross dissolving) is performed to generate the intermediate images. There have been many algorithms proposed for image morphing. Some of the most popular approaches are mesh warping, field warping, and energy-based warping. In mesh warping [7], features are specified by a non-uniform control mesh, and the warping function is usually generated by a spline interpolation. This class of mesh warping algorithm usually shows good distortion behavior, but it has a critical drawback in specifying features since the features on the control mesh may have an arbitrary structure. It is also time consuming to define the feature correspondence via a user interface. In field morphing [3], a pair of corresponding lines (control lines) is specified. The mapping of a point in the vicinity of a line can be determined by its distance from the line. In the case of multiple line pairs, the warping of a given point is calculated by a weighted sum of mappings of all line pairs. This method is easy to user to specify corresponding features. However, sometimes a part of the image may appear in unrelated regions in the in-between images (often referred to as "ghosts"). Energy minimization-based warpings usually guarantee the one-to-one mapping property, which prevents the warped image from folding back upon itself. For example, in Lee *etal.'s* work [5], points, polylines, and curves are sampled and reduced to a collection of points. These points are then used to generate the warping function by minimizing an energy functional. A similar method has been applied to facial morphing based on Navier elastic body spline [8]. All of the above approaches fall into the landmark-based category and require user inputs of the corresponding features [9].

2.2 Field Morphing

The field warping [3] takes the samples of pixel that will match to the destination image from the source image through the reverse mapping of each pixel unit. Under the source image, what pixel is to match to is calculated by the sum of weight of the pairs of the control lines that would make a pair between the source image and the destination image. Unlike the other warping algorithm, the field warping algorithm is not in a formation of polygonal mesh but carries out the control in the form of line. After setting the control lines that are mutually matched to the source image and the destination image, this algorithm carries out the metamorphosis by using the ratio of the control line length and the distance from each individual pixel to each control line.

Each control line effects slightly on all pixels in the image, and when the multiple control lines are used, the weight on each control line for pixel is allotted. The weight is proportional to the length of the control line, and is inverse proportion to the distance separated from the control line. Therefore, when the control line is drawn, as the distance to the control line is further away, it would have less effect on the applicable pixel.

The single line case falls out as a special case of the multiple line case, assuming the weight never goes to zero anywhere in the image. The weight assigned to each line should be strongest when the pixel is exactly on the line, and weaker the further the pixel is form it. The equation for weight is

$$weight = \left(\frac{length^p}{(a + dist)} \right)^b \qquad (1)$$

where *length* is the length of a line, *dist* is the distance from the pixel to the line, and *a*, *b*, and *p* are constants that can be used to change the relative effect of the lines.

If *a* is barely greater than zero, then if the distance from the line to the pixel is zero, the strength is nearly infinite. With this value for *a*, the user knows that pixels on the line will go exactly where he wants them. Values larger than that will yield a more smooth warping, but with less precise control. The variable *b* determines how the relative strength of different lines falls off with distance. If it is large, then every pixel will be affected only by the line nearest it. If *b* is zero, then each pixel will be affected by all lines equally. Values of *b* in the range [0, 2, 5] are the most useful. The value of *p* is typically in the range [0, 1]; if it is zero, then all lines have the same weight, if it is one, then longer lines have a greater relative weight than shorter lines. The field warping is easier to set the control line compared to the mesh warping and is relatively less sensitive to the location or length of control line. All pixels are warped along the control line that the different result would be provided depending on how the control line is given. However, the field warping is calculated for all pixels in the image on all control lines that it is slower by the relatively larger complexity. The time to generate the warped image is proportional to the number of pixel and the number of control line within the image frame [4].

3. PROPOSED SEMI-AUTOMATIC FIELD MORPHING

The proposed method extracts the shape boundary of a pair of morphing object from the source image and the destination image using the morphological segmentation method [10]. Thereafter, on the shape boundary of a pair of morphing object, the user only designates a small number of the pairs of external

control points manually. Based on the designated pairs of external control points, after automatically setting the control lines that are mutually corresponding to the source image and the destination image by the polygon-based vertex selection, the field morphing is performed using the ratio of the control line length and the distance from each individual pixel to each control line.

3.1 Image Segmentation

This study extracts the marker independently from the monotone region and from the texture region separated based on multiscale gradient images and uses the morphological segmentation method [10] that effectively preserves shape boundary of the object.

3.2 Designation of External Control Points

When the shape boundary of the source image and the destination image is extracted and provided, input at least one or more external control points that can express well the global features of morphing object on the contour of the source image by user input. Thereafter, input the same number of external control points that responds to the source external control points on the contour of the destination morphing object and take them as the pair of external control points. The term of 'semi-automation' is used to imply that the control points are manually designated by the user input.

At this time, because each pair of the external control points is selected by the user input, the number of selecting the pairs needs to be minimized for user convenience, within the scope of not making a great impact on the performance of field morphing. In addition, it is very important to consider the global features between the source morphing object and the destination morphing object appropriately and select such points that can increase the possibility of having the more natural morphing results.

3.2.1 Polygon-based Vertex Selection

At the state that shape boundary of the pairs of morphing object is obtained from the source image and from the destination image, the user manually designates a small number of external control points that are mutually corresponding to the source morphing object and the destination morphing object. The designated external control points are taken as the references to segment the shape boundary of the source morphing object and the shape boundary of the destination morphing object by each partial contour unit. Thereafter, for the source morphing object and the destination morphing object that are segmented by the partial contour unit, the polygon-based vertex selection [11-13] is performed independently to search for vertices that approximates the contour of morphing objects.

Fig. 1 illustrates the process that performs the polygon-based vertex selection on the partial contour of morphing object. Here, slanted squares are external control points manually selected by the user input, and black squares are newly selected vertices,

while gray squares indicate support points. Also, D_{max} is the predetermined maximum tolerable distortion, c_i is a index of pixels on the partial contour section, and $d(c_i, c_j)$ means the distance between c_i and c_j.
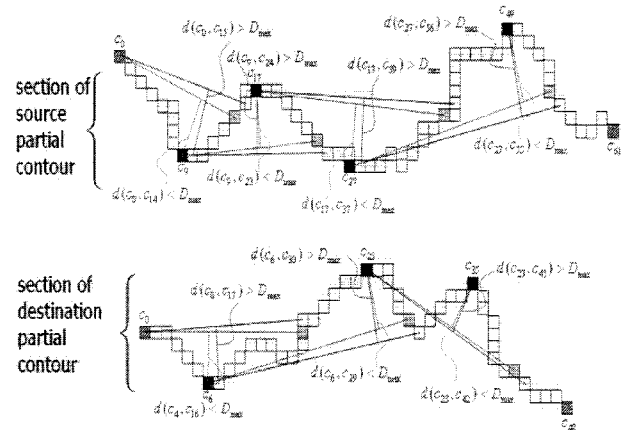

Fig. 1. Example of Polygon-based Vertex Selection

First, out of one or more external control points, the first external control point is set as a vertex and at the same time it is set as a starting vertex. In the partial contour section between the first external control point and the following external control point, a temporary support point is sequentially selected by pixel unit. In addition, the maximum distortion is obtained from contour segment section and the polygon side formed by the temporary support point and the starting vertex. By comparing the maximum distortion with the predetermined maximum tolerable distortion (D_{max}), if the maximum distortion is larger, select the location of pixel that has the maximum distortion distance in the previous temporary support point section as the new vertex. If not, the process of taking the next pixel as the temporary support point is repeated. Assign the newly set vertex as the new starting vertex to process thereafter and repeat the process of performing the polygon-based vertex search to the next external control point.

By applying the above process to all partial contours of the source morphing object and of the destination morphing object repeatedly, find all the polygonal approximation vertices of them.

3.2.2 Adaptive Control Line Mapping

Once all the polygonal approximation vertices are available on the source morphing object and the destination morphing object, a comparison is made for the number of vertices included in the partial contour section of the source morphing object and the partial contour section of the corresponding destination morphing object by each pair of partial contour. Then take the partial contour with more vertex numbers as the reference partial contour and take the other partial contour as the corresponding partial contour. Like this, if control point mapping is performed based on the section with more vertices, it will greatly enhance the performance of the field morphing

because adaptive mapping is performed centered on the section that contour shape is complicated. Next, set all the vertices included in each reference partial contour as the reference control points. Then, earn the ratio of contour length between two partial contours, and repeatedly obtain the length from each reference control point of each reference partial contour to the contour point that exists in the middle between the two consecutive control points, toward all the reference control points included within each reference partial contour.

Thereafter, in order to determine all the corresponding control points that correspond to the reference control points, set the starting external control point of each corresponding partial contour as the first corresponding control point and at the same time as the starting support point. Set the location point that moved along the contour segment for the distance that multiplies the length of corresponding middle contour point by the length ratio of partial contour, as an ending support point. Then, select the pixel point that has the maximum distortion distance between the contour segment and the polygonal sides formed by the starting support point and the ending support point, as the new corresponding control point and assign the ending support point as the new starting support point. Then repeat the process of finding all the corresponding control points of each corresponding partial contour section until the next corresponding external control point.

Fig. 2 shows an example of finding corresponding control points during the adaptive mapping process of the control points. Here, the slanted squares are the control points manually provided by the user input, the black squares are newly selected corresponding control points, and the gray squares are the support points.

(a) Process of control line mapping
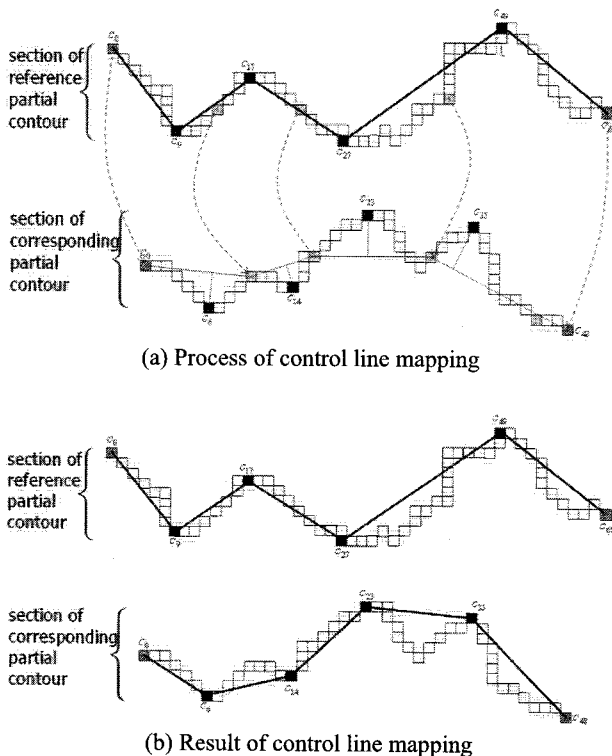

(b) Result of control line mapping

Fig. 2. Example of search for corresponding control points using the adaptive mapping

Through the above process, semi-automatic field morphing can be realized by mapping the pairs of control lines that mutually correspond to the source image and the destination image, and then using the ratio of the control line length and the distance from each individual pixel to each of the control line.

4. SIMULATION RESULTS AND CONSIDERATIONS

In order to evaluate the performance of the proposed method, a computer simulation was performed, taking Fabio's middle-aged passport picture with the dimensions of 256×300 as the source image, while taking Fabio's young passport picture with the dimensions of 256×300 as the destination image. In the process of reverse mapping for morphing implementation, an image interpolation technique is required to generate a new pixel value. The presented simulation results use the nearest neighbor interpolation. Fig. 3 shows shape boundary of the source image and the destination image, respectively.

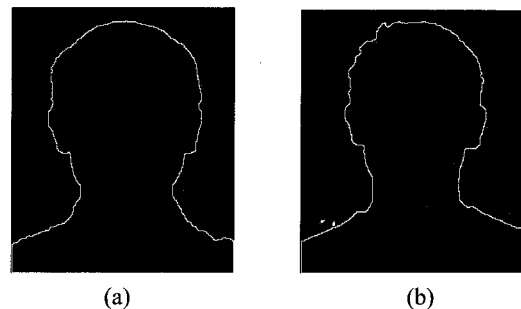(a)   (b)

Fig. 3. Shape boundaries of the morphing objects: (a) Source image, Fabio (middle-aged), (b) Destination image, Fabio (young)
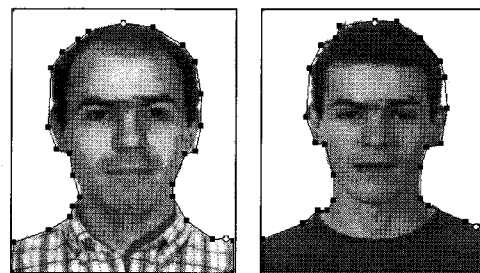

Fig. 4. A pair of entire control lines of source image and destination image using two external control points and

$$D_{max} = 5$$

Fig. 4 shows pairs of control lines of source image and destination image using two control points and $D_{max} = 5$. Fig. 5 is the simulation result that uses one external control point set by the user input and $D_{max} = 3$. Fig. 6 is the simulation result using two external control points and $D_{max} = 3$. In Fig. 4, Fig. 5, Fig. 6 and Fig. 7, the white dots are the external control points manually selected by the user input, and the black dots are the pair of control points automatically extracted between the external control points. As shown by the comparison of Fig.

5 and Fig. 6, it can be easily found that more natural morping results can be obtained when relatively more external control points are input by the user.

When performing the field morphing of a person, the pairs of control lines on major facial parts such as eyebrows, eyes, nose, and mouth, have to be designated in order to perform natural morphing of internal shape. Additional studies are necessary automatic alignment algorithm to make these processes automatic.

Fig. 7 shows a simulation result that is naturally morphed from the middle-aged Fabio to the young Fabio by providing additional external control lines on the contour part of the hair and the featured part of face by the user input in addition to the two external control points.
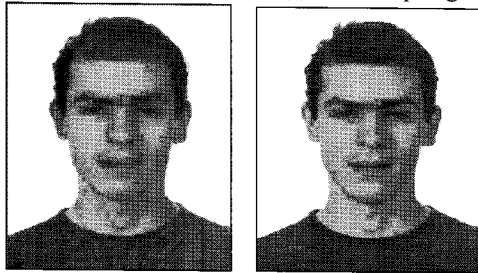

(a) A pair of control lines of source image and destination image
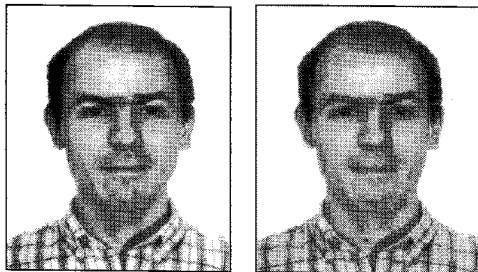
(b) 0% morphing   (c) 20% morphing

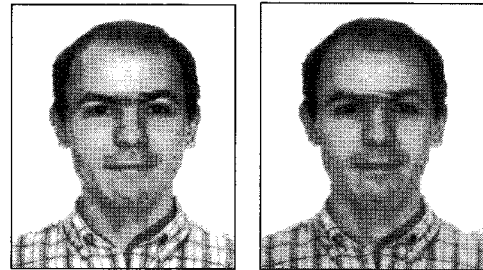

(d) 40% morphing   (e) 60% morphing
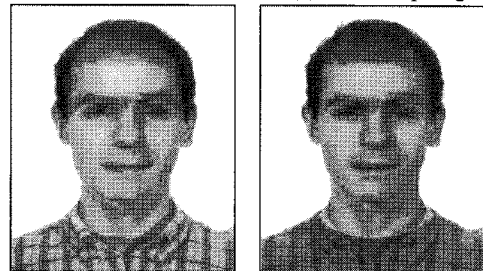

(f) 80% morphing   (g) 100% morphing

Fig. 5. Morphing results using one external control point and

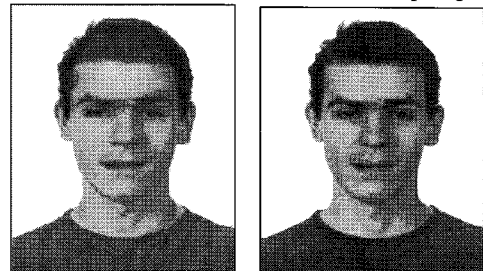$$D_{max} = 3$$

(a) A pairs of control line of source image and destination image

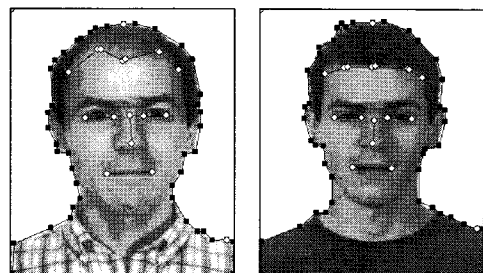(b) 0% morphing   (c) 20% morphing

(d) 40% morphing   (e) 60% morphing

(f) 80% morphing   (g) 100% morphing

Fig. 6. Morphing results using two external control points and

$$D_{max} = 3$$

(a) Control lines on source image and destination image

(b) 0% morphing   (c) 20% morphing

(d) 40% morphing   (e) 60% morphing
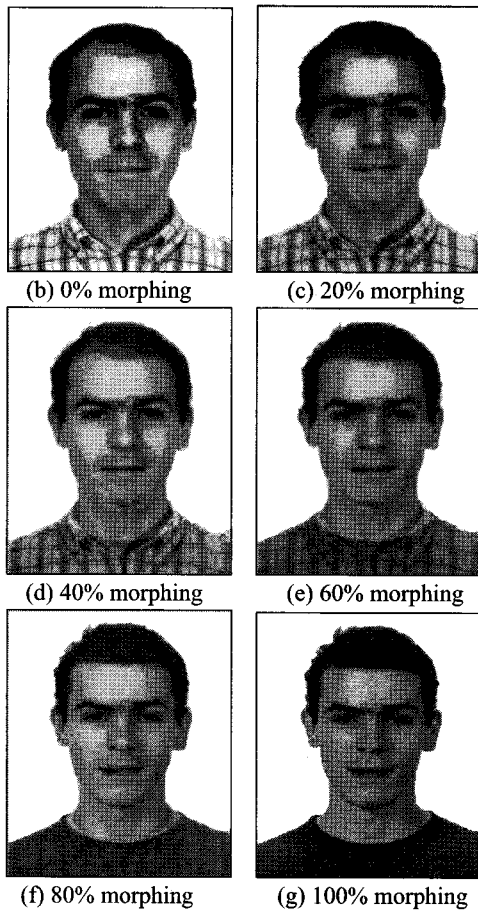
(f) 80% morphing   (g) 100% morphing

Fig. 7. Morphing images using 2 external control points, $D_{max} = 3$ and additional external control points

As we can see from the above simulation results, the mapping of the perfect pairs of control lines may not be available between the source image and the destination image when using the proposed method, but very natural field morphing results can be obtained although the process is semi-automatic. The proposed method creates visually fluid morphs and warps with an easy-to-use interface.

5. CONCLUSIONS

This paper suggests a semi-automatic field morphing technique that can provide fine quality morphing results only by inputting a few number of external control points and by going through polygon-based vertex selection and the adaptive mapping of control lines, after the shape boundary of the morphing object is obtained.

The proposed method clearly reduces user input times to set the pair of control lines and assists an unskilled person to select desirable mapping pairs based on the polygonal approximation vertices.

In the proposed semi-automatic field morphing algorithm, the image segmentation characteristics not only effects critical influence on the image morphing result but to be the basis of automation algorithm. To this point, multiple number of image segmentation algorithm has been proposed, No the image

segmentation technique that can perfectly extract the desired object regardless of the complexity or contrast of background for the features of the 2D images. Hence, the proposed method has shortcomings in that it has to be applied to the image existed in foreground on the very simple background like blue screen or it should know the shape boundary of morphing object in advance. Obviously, during the course of image segmentation, the images with more complicated backgrounds may be applicable in the event that the user input is used or in the event that the complete shape boundary is not used for the characteristics of its application field. When the proposed method is applied to the relevant fields, low cost and high quality of generating the applied contents can be expected due to the automation of morphing and image warping. Moreover, it is expected to generate various technological dispersion effects on the relevant fields.

However, the proposed method has disadvantages in that a use has to set even a few external control points directly and there are various limitations to the images to be processed. In the future, there is a need of making additional studies to resolve the problems in systematic approach.

Therefore, future studies need to work to achieve full-automation without the user input. For this purpose, as mentioned earlier, it should appropriately consider the image characteristics between the source morphing object and the destination morphing object within the limited time, and at the same time, a higher location point with the possibility of obtaining natural morphing result and develop the algorithm that is intelligent to make automatic mapping with the pair of control points.

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