Image Morphing with the Beier-Neely Method

Feng Zhu

University of Victoria

fengzhu@uvic.ca

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Overview

Image Morphing

- **Image Morphing** is an image processing technique to turn one image into another through a smooth transition.
- Source image is where the morphing starts.
- Target Image is where the morphing ends.
- Intermediate frames are the morphed images.

(a) (b) (c) (d)

Figure 1.1 : Image morphing

Application: Movie Special Effects

- First movies with morphing
  - *Willow*, 1988
  - *Indiana Jones and the Last Crusade*, 1989
- First music video with morphing
  - *Black or White*, Michael Jackson, 1991
- Disney animations with speeding production
  - Mickey Mouse
  - SpongeBob SquarePants
  - Gopher Broke

Morphing Techniques

- Wolberg, Mesh-Based Image Morphing, 1990.

  Relates image features with meshes; Interpolate between mesh nodes to generate frames in the transformation.
- Beier and Neely, Feature-Based Image Morphing, 1992.

  Relates image features with directed line segments; Interpolate between line segments to generate frames.
- Wolberg, Thin-Plate Spline Interpolation Method, 1998.

  Apply surface interpolation over scattered data; Find a “minimally bended” smooth surface passing through all given points.

Image Blending

- Pixel-by-pixel color interpolation
- Produce cross-dissolving visual effect

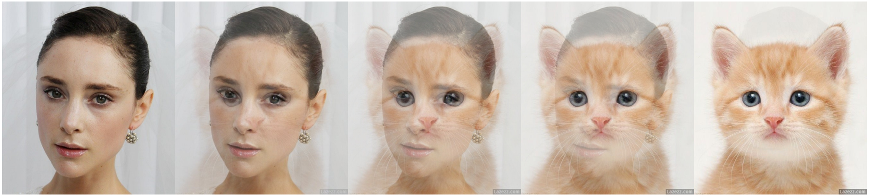


Figure 2.1 : Image cross-dissolving

- artificial, non-physical, with "double image" effect
- apply **image warping** to align object features in both images

Image Warping

- Warping performs coordinate transformations to distort spacial configuration of images.
- Warping maps each pixel from one position to another.

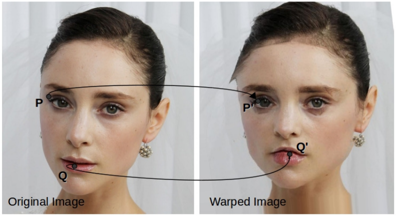


Figure 2.2 : Image warping

Image Morphing in General

- Image Morphing = Image warping + Image blending

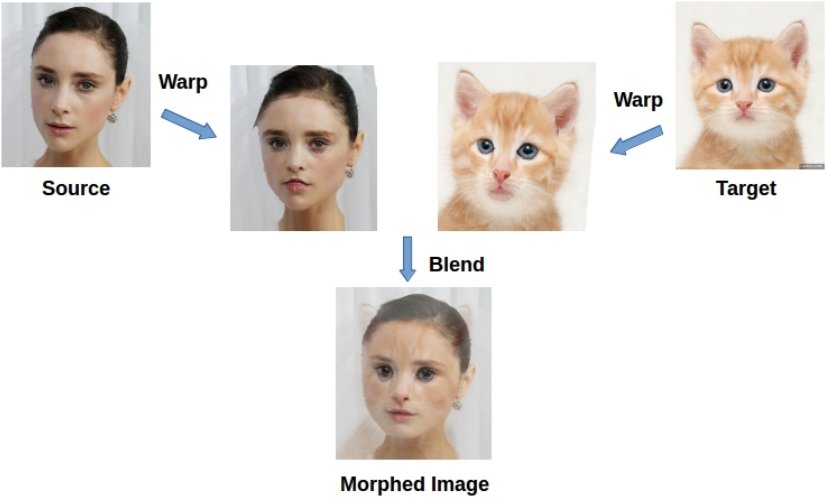


Image Morphing in General

Algorithm 1 General image morphing algorithm

Input: source image S, target image D
Output: a sequence of morphed images $\{I_t\}_{t=0}^{1}$

for each intermediate frame at stage $t \in [0, 1]$ **do**
  Warp image S: $W_S = \text{warp}(S, t)$
  Warp image D: $W_D = \text{warp}(D, t)$
  Blend W_S and W_D: $I_t = \text{blend}(W_S, W_D, t)$
endfor

Since image blending is the same for all morphing algorithms, the difference lies in the image warping process.

Feature-based image morphing technique:

- Performs warping by using object features
- Features are **user-specified** directed **line segments**
- One-to-one correspondence between features

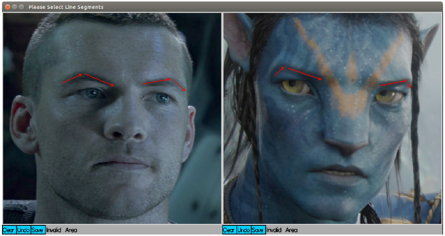
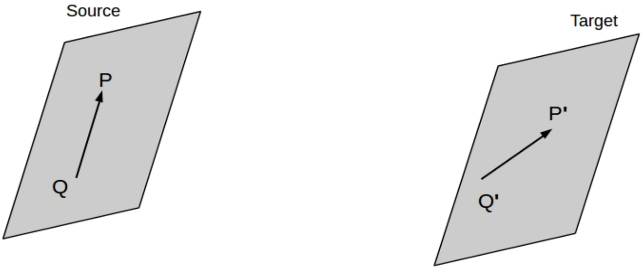


Figure 2.4 : Feature line segments

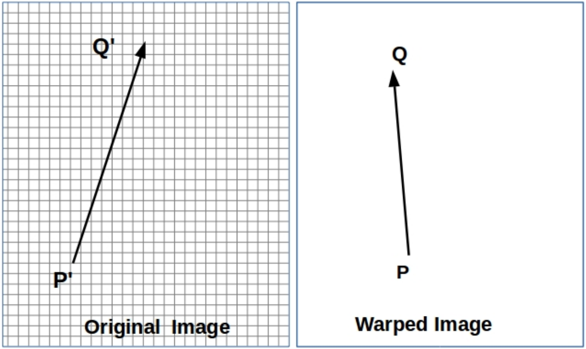
Liner Line-Segment Interpolation

- Morphing result consists of a sequence of intermediate frames
- Each frame is computed with its corresponding feature line segments
- Interpolate between feature line segments in source and target images



Warp with One Line-Segment Pair

1. v: the perpendicular distance from X to line PQ
2. λ: the distance from P to the projection of X
3. $\lambda/||PQ|| = \lambda'/||P'Q'||$



Warp with One Line-Segment Pair

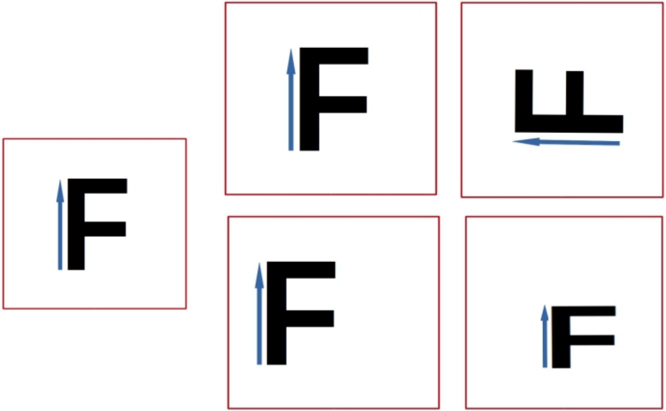


Figure 2.5 : One line-segment pair example

Warp with Multiple Line-Segment Pairs

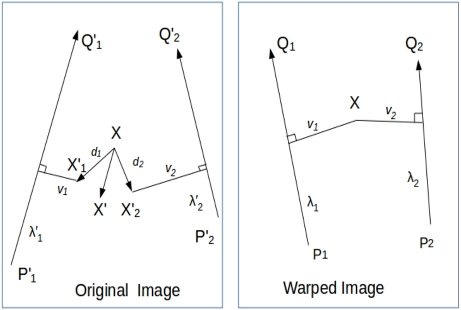


Figure 2.6 : Transform with multiple features

- Each feature line segment is associated with a **weight** determining the influence
- weight $= \left(\dfrac{\text{length}^p}{a + \text{distance}} \right)^b$
- a, b, and p control the influence of distance, weight, and length

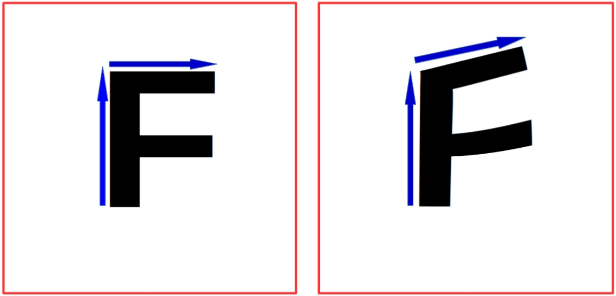


Figure 2.7 : Multiple line-segment pair example

Software: Overview

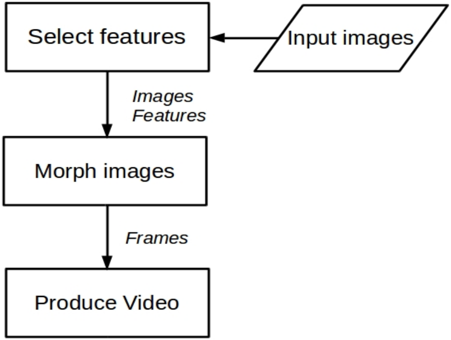


Figure 3.1 : Software structure

The software consists of three programs:

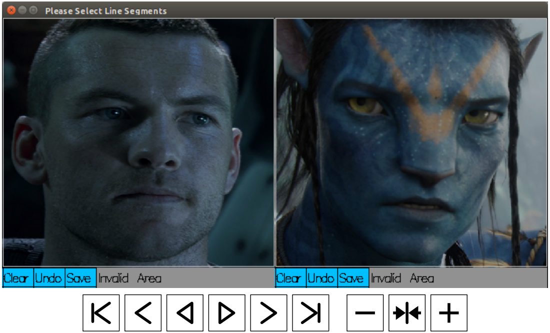
- `select_features`
- `morph_images`
- `frames_to_video`

Tools and Libraries

- Linux system with C++ a compiler that supports C++ 11
- Libraries such as SPL, CGAL, OpenGL, GLUT, and STL
- Free software FFmpeg
- Versions of tools verified to work:
  - GCC 4.8.2
  - SPL 1.1.15
  - CGAL 4.5.2
  - OpenGL/GLUT 3.0
  - FFmpeg 2.5.3

`select_features` Program

- Graphical User Interface (GUI): Manually select feature line segments
- **Input**: image files, names of corresponding feature data files
- **Output**: data files with feature line segments



Feature Data File

man1.dat

```
28
132 333 171 356
183 358 262 331
325 337 396 340
404 340 424 311
298 326 298 216
218 144 287 147
293 147 335 144
```

Figure 3.2 : Feature data file

- Entry indicates the number of features in the file
- Each line contains the endpoints of a feature line segment

`morph_images` & `frames_to_video` Programs

`morph_images`:

- **Input**: image files, corresponding feature data files
- **Output**: a sequence of intermediate frames (e.g., morphed images)
- **Options**: number of frames, basename, warping parameters, ...

`frames_to_video`:

- **Input**: intermediate frames
- **Output**: a video displaying the morphing result

Morphing Result

Analysis

- Achieve satisfactory morphing visual effect
- Performance with 720$\times$486 size, 100 features
  - 2 min/frame on SGI 4D25 (CPU 20MHz, Memory 64 MB)
  - 2 secs/frame on ASUS X455L (CPU 3.1GHz, Memory 8GB)
- Advantages and Disadvantages:
  - Expressive: Only the user-specified features affect the morphing, and others are blended smoothly
  - Efficient: Drawing line segments VS placing dozens of mesh points
  - Speed: Global computation, all the line segments need to be referenced for every pixel, slows down the speed

Conclusion

- **Summary**
  - Beier-Neely morphing algorithm produces reasonable results
  - Our software has implemented the Beier-Neely method effectively
- **Future Work**
  - Automatic feature detection to reduce the amount of work
  - Combine points, curves, and line segments

References

T. Beier and S. Neely (1992)
Feature-Based Image Metamorphosis
ACM SIGGRAPH Computer Graphics 26(2), 35-42

G. Wolberg (1998)
Image morphing: a survey
The visual computer 14(8), 360-372

A. V. Feciorescu (1020)
Image morphing techniques
Journal of Industrial Design and Engineering Graphics 6(1), 25-28

Linear Line-Segment Interpolation

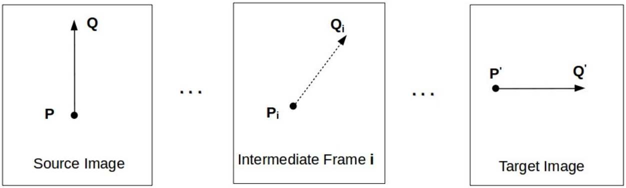


Figure 6.1 : Linear interpolation

- Calculate feature line segments for each intermediate frame
- Given PQ and $P'Q'$, generate $\{P_iQ_i\}_{i=1}^{N}$ by interpolation
- Incremental step ΔP: $\Delta P = (P - P')/N$, $\Delta Q = (Q - Q')/N$
- For P_iQ_i: $P_i = P + \Delta Pi$, and $Q_i = Q + \Delta Qi$

Calculations

$$X' = P' + u \cdot (Q' - P') + \frac{v \cdot \text{perpendicular}(Q' - P')}{||Q' - P'||}, \tag{1}$$

where

$$u = \frac{\lambda}{||Q - P||}, \tag{2}$$

$$v = \frac{(X - P) \cdot \text{perpendicular}(Q - P)}{||Q - P||}, \tag{3}$$

$$\lambda = \frac{(X - P) \cdot (Q - P)}{||Q - P||}, \tag{4}$$

Parameters a, b, p

$$\text{weight} = \left(\frac{\text{length}^p}{a + \text{distance}} \right)^b, \tag{5}$$

- a determines the smoothness and precision of the user's control over the warping. A lower value of a implies a tighter control but less smooth warping effect. The bigger the a is, the less effect of distance is. (a>0)
- b determines how the influence of different feature line segments decays with distance. A large b means a pixel will only be affected by the closest feature line segment, and a zero value implies every feature line segment has the same relative influence. ($b \in [0.5, 2]$)
- p determines how the length of a feature line segment influences the weight. A zero value means length has no influence and a higher value means weight is affected more by length. ($p \in [0, 1]$)

Detailed Algorithm

Algorithm 2 Algorithm for transformation with multiple feature line-segment pairs

Input: source image S, feature line-segment set $P_1Q_1, P_2Q_2, ..., P_nQ_n$

Output: destination image D

for each pixel with position X **do**
    $D_{\text{sum}} = (0,0)$, $W_{\text{sum}} = 0$
    for each P_iQ_i **do**
        calculate u and v for X based on P_iQ_i
        find X' with the u and v
        calculate displacement $d_i = X' - X$
        calculate the weight weight $= (\text{length}^p / (a + \text{distance}))^b$
        $D_{\text{sum}} = d_i w + D_{\text{sum}}$
        $W_{\text{sum}} = w + W_{\text{sum}}$
    endfor
    $X' = X + D_{\text{sum}}/W_{\text{sum}}$
    copy the value of the pixel at X' to that of the pixel at X: $D(X) =$

Special Cases

Algorithm 3 Special cases

if X' falls outside the image domain **then**
  find the pixel coordinate X'_C closest to X' on the boundary of the source image
  update X': $X' = X'_C$
endif
if X' contains non-integer coordinate **then**
  find the pixel coordinate X'_I by interpolating the neighbours of X' and rounding the interpolation result
  update X': $X' = X'_I$
endif