

## Tutorial: Warping and Morphing

1. Explain what is meant by the following equation:

$$\text{morphing} = (\text{warping})^2 + \text{blending}$$

2. In the algorithm developed by Beier and Neeley pairs of lines are used to specify the warping. In a concrete example two pairs of lines specify a 2D warping: In the source image the line  $L_1$  starts at (1, 1) and ends at (1, 9). The line  $L_2$  starts at (9, 2) and ends at (9, 8). In the target image the corresponding line  $L_1'$  starts at (1, 1) and ends at (1, 9) while  $L_2'$  starts at (3, 2) and ends at (9, 2). Calculate where the pixel  $\mathbf{p} = (5, 5)$  in the source image would map to in the target image. Assume that the constants controlling the warping are  $a = b = p = 1$ .
3. An image with 300 x 175 pixels is warped using a two-dimensional free-form deformation based on linear B-splines defined by a 6 x 6 mesh of control points.

- a. Calculate the spacing between control points in pixels.
- b. Calculate the pixel coordinates for the following B-spline integer lattice coordinates  $i, j$  and the fractional lattice coordinates  $u, v$ :

- i.  $(i, j) = (1, 1)$  and  $(u, v) = (0, 0)$
- ii.  $(i, j) = (1, 1)$  and  $(u, v) = (0.5, 0.5)$
- iii.  $(i, j) = (1, 3)$  and  $(u, v) = (0.75, 0.2857)$

- c. Calculate the B-spline integer lattice coordinates  $i, j$  and the fractional lattice coordinates  $u, v$  for the following pixels:

- i.  $(x, y) = (120, 140)$
- ii.  $(x, y) = (100, 100)$
- iii.  $(x, y) = (150, 130)$

- d. Calculate the new location of a pixel  $(x, y) = (135, 122.5)$  after warping. The matrix of control points looks as follows:

(1, 4)	(-3, 7)	(3, 8)	(4, 7)	(0, 1)	(2, 3)
(-3, 7)	(-2, 9)	(2, 7)	(3, 1)	(2, -2)	(2, 2)
(4, 2)	(3, 8)	(2, 1)	(4, 2)	(2, 1)	(3, 1)
(3, 2)	(2, 9)	(-3, 8)	(6, 8)	(3, 4)	(3, 5)
(-1, 3)	(-2, 3)	(1, 3)	(2, 3)	(8, 3)	(-4, 2)
(0, 0)	(-2, 1)	(1, 1)	(-2, 2)	(1, 2)	(0, 0)