6.815/6.865 Digital & Computational Photography

Problem Set 6: Morphing

Due Friday, April 1 at 7:00pm

Morphing

In this assignment you will implement a triangulation based warping method, and then use it to perform morphing. You can use your technique to achieve a variety of very cool (but often very tacky) special effects.

Warping Given an image (*unwarped*), we want to deform it according to a warp. As discussed in lecture, you want to perform the inverse warp to obtain good results. That is, find out the color of each pixel in the warped image by mapping its (*warped*) coordinates to the unwarped ones. We're given a small set of input (*warped!*) pixel coordinates $p_1, \ldots, p_n$ and their corresponding output (*unwarped!*) pixel coordinates $\tilde{p}_1, \ldots, \tilde{p}_n$. Be careful: the *input* coordinates are in the *output* image, that's why we call it the *inverse* warp. You will also need to implement the forward warp for comparison and, hopefully, you will conclude that the inverse confusion was worth it.

Suppose we define a triangular mesh over the input coordinates $p_1, \ldots, p_n$. We can apply this same triangulation to the output pixel coordinates and produce a triangle-to-triangle correspondence between the two images. We can then use barycentric coordinates to define a pixel-to-pixel mapping between each corresponding triangle.

For any point p, located in a triangle with vertices p_0, p_1, p_2, the barycentric coordinates $\lambda_0, \lambda_1, \lambda_2$ are defined such that:

$$p = \lambda_0 p_0 + \lambda_1 p_1 + \lambda_2 p_2 \tag{1}$$

$$\text{and } \lambda_0 + \lambda_1 + \lambda_2 = 1. \tag{2}$$

If we replace the vertices p_0, p_1, p_2, with the vertices, $\tilde{p}_0, \tilde{p}_1, \tilde{p}_2$, from the corresponding triangle in the output mesh and use the same barycentric coordinates will we get the corresponding pixel $\tilde{p}$ in the output image:

$$\tilde{p} = \lambda_0 \tilde{p}_0 + \lambda_1 \tilde{p}_1 + \lambda_2 \tilde{p}_2.$$

Given a point p, and vertices p_0, p_1, p_2, the barycentric coordinates can be solved for using equations (1) and (2). There are 3 unknowns, $\lambda_0, \lambda_1, \lambda_2$, and 3 equations (equation (1) holds for both the x and y coordinates).

Problem 1 (6.815/6.865)

Write a script `checkerwarp.m` that loads the provided `checkerboard.png` image and generates the warped image according to the following displacements:

$$\begin{aligned}(32, 32) &\rightarrow (88, 58)\\ (224, 32) &\rightarrow (229, 82)\\ (224, 224) &\rightarrow (165, 212)\\ (32, 224) &\rightarrow (61, 178)\end{aligned}$$

In your script, implement both (incorrect) forward warping and (correct) inverse warping. In the forward warp, your main loop is over the pixels of the unwarped image and you *scatter* the pixel colors. In the inverse warp, your main loop is over the pixels of the warped image and you *gather* the pixel colors.

You can use the MATLAB `delaunay` function in order to triangulate your mesh, and `tsearch` to search the triangulation. Remember to add feature points that keep the corners of the images unwarped. Use bilinear interpolation (e.g. MATLAB `interp2` function) to lookup the color at fractional pixel locations.

You'll be using the same code for the next two problems, so it might be beneficial for you to write a general warping function. This isn't required, though.

In your writeup: Paste your results for both forward warping from input coordinates to output coordinates, and inverse warping from output to input coordinates. Summarize what your code does to get those results and describe any problems you've found with either method.

Problem 2 (6.815/6.865)

Load the images `face1.jpg` and `face2.jpg` and their corresponding feature points from the provided `facepts.mat` file (loading the MAT file creates two matrices `facepts1` and `facepts2` in your MATLAB workspace). Compute the result of warping the feature points for `face1` to their corresponding feature points for `face2`. Put your code in a script called `facewarp.m`. Again, remember to add correspondences that keep the corners of the image fixed.

In your writeup: Display the warped `face1` image that you generated.

Problem 3 (6.815/6.865)

With image warping completed, we're ready to perform morphing. Let's say you want to compute an image that's partially between the two faces (say, $0 \leq t \leq 1$ where 0 corresponds to `face1.jpg` and 1 corresponds to `face2.jpg`). Here's how you do it:

- Linearly interpolate the feature points from both images to produce a set of intermediate warping positions: `(1-t)*facepts1 + t*facepts2`.
- Warp both images to the intermediate positions.

- Linearly blend the two images from the previous step (again using $(1-t)$ and t as blending weights.

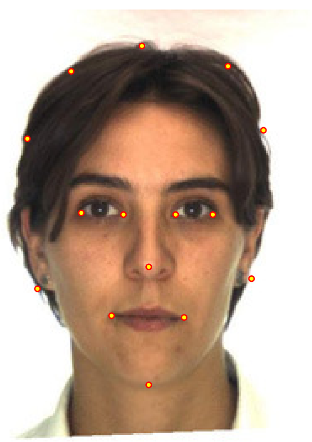
The interpolation and blending should be weighted so that you can smoothly go from one image to another. Write this code in a script called `morph.m`.

In your writeup: Show a morphing sequence of maybe five or six images that goes from `face1.jpg` to `face2.jpg` using evenly spaced values of t between 0 and 1.

Problem 4 (6.815/6.865)

We want to generate a movie of the class morph using warping and morphing. If you were not present in the class when we took your pictures, we ask you to prepare your own 256 x 256 pixel photo and make sure that your face in your photo is roughly aligned to the face in `face1.jpg` and share it with the student listed above you in `emails.pdf`. If you are the first in the list, please send your photo to the last student in the list.

Load your photo and your classmate's photo and click matches using MATLAB `subplot` and `ginput`. We recommend you to click 15 matches. Save your clicks as two matrices `facepts1` and `facepts2` in `myfacepts.mat`.



Generate a morphing sequence of thirty images that goes evenly from your photo to your classmate's photo. Write this code in a script called `class_morph.m`. We will combine the submitted sequence into a movie of the class morph. Note that in `emails.pdf`, you have a number to the right of your name. Save each image in your morphing sequence in "`your number + the frame number.JPEG`". For example, if your number is 12, your image will be from `1201.jpg` to `1230.jpg`.

In your writeup: Although you generate and save a sequence of thirty images, in your writeup, show a partial sequence of six of them that goes evenly from your photo to your classmate's photo as you did in Problem 3.

Problem 5 (6.865 only)

This problem is for 6.865 only, and unlike the previous problems, it's going to be all reading and writing. Your job is to review a recent publication in computational photography. This will hopefully give you some more insight into the review process that these papers go through, and perhaps help you come up with ideas about your final project (and in case you were concerned, we don't expect your final project to be publication-quality, but it's still helpful to keep the review criteria in mind).

You should select one paper from the provided `papers.html` file. If there's another relevant paper that you're particularly interested in reading, ask us about it and we'll probably be okay with it (unless it's something that you're already supposed to read for one of the problem sets).

You should use the SIGGRAPH review form, available at the following URL:
`http://www.siggraph.org/s2005/main.php?f=cfp&p=papers&s=reviewform`. You may omit the numerical ratings from questions 5 and 6. For question 8, try to come up with at least one outstanding question that you think the authors didn't address in the paper. You can skip question 9. You should put your review in your PDF file along with everything else. Try to be thorough! Probably a paragraph or two for each question, and significantly more for question 7.

One final note: don't be compelled to like a paper because it was already published. Every paper has some shortcomings. Maybe the method is very elegant and general but doesn't end up producing very impressive results. Maybe the results are spectacular, but the method itself has some mathematical holes. Maybe everything seems great, but there just aren't enough details to reproduce the results. It's up to you as a reviewer to weigh the strengths and weaknesses of each paper.

Submission

Like the previous assignments, you should assemble a ZIP file that is named after your Athena login. Make sure this file contains:

- A PDF file with your results and (if you're in 6.865) your review.
- Your MATLAB code:
  - `checkerwarp.m`
  - `facewarp.m`
  - `morph.m`
  - `class_morph.m`
  - `myfacepts.mat`
  - `JPEG` images in your class morph
- Any images (other than the provided ones) that might be necessary to run your code.

All submissions are due by April 1 at 7pm.