6.815/6.865 Digital & Computational Photography

Problem Set 8: Automatic Panoramas

Due Friday, April 15 7:00pm

Automatic Panoramas

In the previous homework, you manually selected the corresponding pixels in two images to estimate a homography. In this problem, you'll eliminate the manual selection of the corresponding pixels by using SIFT features and the RANSAC algorithm.

Before explaining the automatic estimation, let's review how to compute the 2D homography matrix H given 2D point correspondences $x_i \leftrightarrow x_i^{'}$, such that $x_i^{'} = Hx_i$. Note that you should normalize the points before computing H as follows:

1. Normalization of x: Compute a transformation T, consisting of a translation and scaling, that takes points x to a new set of points $\widetilde{x}_i$ such that the centroid of the points $\widetilde{x}_i$ is the coordinate origin $(0,0)^T$, and their average distance from the origin is $\sqrt{2}$.
2. Normalization of x': Compute a transformation T' for the points in the second image, transforming points $x_i^{'}$ to $\widetilde{x}_i^{'}$.
3. Linear system: Solve $\widetilde{H}$ such that $\widetilde{x}_i^{'} = \widetilde{H}\widetilde{x}_i$.
4. Demormalization: Set $H = T'^{-1}\widetilde{H}T$

Now let's get rid of the manual selection. Run SIFT on each image, and then find the nearest neighbor from one image to the other one. To compute feature points, use David Lowe's SIFT keypoint detector `http://www.cs.ubc.ca/~lowe/keypoints/`. Finally, you're ready to estimate H using the RANSAC algorithm. This robust estimation algorithm is used to fit a model to data and separate inliers from outliers. This is done as follows:

1. Select a random sample of P correspondences and compute the homography H. For homography estimation, the sample size P is 4.
2. Determine the set of inliers which are within a distance threshold t. Use the symmetric transfer error, which is the square of Euclidean distance between a pair of points and their transform: $d(\widetilde{x}_i, \widetilde{H}^{-1}\widetilde{x}_i^{'})^2 + d(\widetilde{x}_i^{'}, \widetilde{H}\widetilde{x}_i)^2$. Note that point coordinates are normalized to that their mean distance from the origin is $\sqrt{2}$. The value of t should be set relative to this, say in the range 0.001 - 0.01.
3. After N trials, choose the H with the largest number of inliers.

4. Re-estimate H from all correspondences classified as inliers.

Problem 1 (6.815/6.865)

For each input image, find feature points using Lowe's SIFT keypoint detector. Implement your own correspondence estimation that finds the nearest neighbor by comparing the sum of squared difference and discards matches for which the ratio of the nearest neighbor distance to the second nearest neighbor distance is greater than 0.7. Write a script `find_matches.m` that loads the two input images, runs Lowe's SIFT detector, finds matches, and display matches by drawing lines connecting the matches.

In your writeup: Show the results of your code for finding matches between your two of own images. Display two input images side by side along with the resulting matches, and draw lines connecting the matches.

Problem 2 (6.815/6.865)

Implement the RANSAC algorithm. In this problem, the number N of trials is fixed to 1000. Write a script `ransac_homography.m` that normalizes the pixel coordinates of the initial matches from Problem 1, and estimates a best-fitting homography using RANSAC.

In your writeup: Display two input images side by side and plot the resulting inliers using colored lines connecting them, compare the number of inliers and the number of initial matches, and note the distance threshold t that you used. Create an automatic panorama using at least four of your photos and display the placement of each individual image should be represented as a (warped) rectangle as you did in the previous pset. Also, please shortly summarize how you implemented the RANSAC algorithm.

Problem 3 (6.815/6.865)

Now we ask you to determine the number of iterations N from a probabilistic point of view. The number of iterations N should be set such that with probability q at least one set of P pairs is free from outliers. Given the proportion of inliers X, X^P is the probability that P matches are all inliers, and $1 - X^P$ is the probability that a set of P matches has some outliers. It is $(1 - X^P)^N$ that there always exist some outliers for N times. What we want is the opposite to this: at least one set of P matches is free from outliers. The probability that there is no outlier for at least one time is $1 - (1 - X^P)^N$, and we want this to be q. This gives us $(1 - X^P)^N = 1 - q$. Taking the log and isolating N, we can write

$$N = \frac{log(1-q)}{log(1-X^P)}$$

The parameter q is usually set to 0.99. The remaining input parameter to be set here is the proportion of inliers X. During each iteration, you update the portion of inliers with the best ratio of inliers that you have found so far. This gives you the number of iterations that you should try. As you find more inliers, your number of iterations to be done decreases. When you reach N trials necessary, stop finding inliers and re-estimate H from all correspondences classified as inliers. Write this adaptive RANSAC in `ransac_adaptive.m`.

In your writeup: Display two input images side by side and plot the resulting inliers using colored lines connecting them, compare the number of inliers to the initial matches, and note the parameters that you used. Create an automatic panorama using at least four of your photos and display the placement of each individual image should be represented as a (warped) rectangle as you did in the previous pset. Also, please provide a summary of the way you realized the adaptive algorithm.

Project Proposal (6.815/6.865)

The deadline for the final product is May 12. By April 15 (the due date for this assignment) you should turn in your project proposal. Please describe the goal of your project and breakdown of tasks to be completed along with a timeline. Also note any potential difficulties that you might encounter as well as any backup plan in case things don't work out.

In general, you should try to persuade us that your project is interesting and that you're capable of completing it. We will provide feedback on your proposal within a few days of receiving them, but you should feel free to contact us beforehand if you have any questions.

Please submit your proposal along with this homework assignment, but in its own PDF file. If you are working with a partner, only one person needs to submit (but make sure both names are on it).

Submission

Submit a ZIP file named after your Athena login. This should contain your writeup (PDF), your project proposal (PDF), your images, and any MATLAB code that you wrote. All submissions are due by April 15 at 7pm.