CS 485/685 – Computer Vision

Programming Assignment 3

(Due April 7)

1. (50 pts) Harris Corner Detector

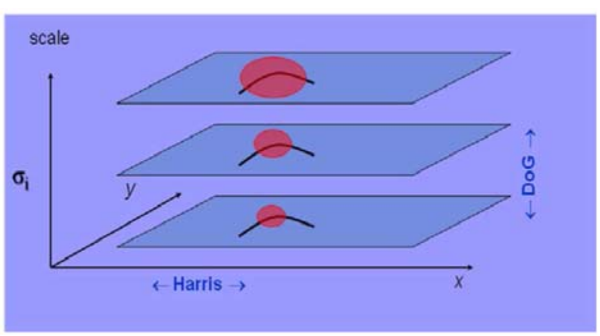
   Implement the Harris corner detector by following the steps discussed in class. Using the test images provided in the "Test" folder, show the following results:

   (a) corner response $R(A_W)$ at each pixel, using $\alpha=0.06$, derivative of Gaussian function, $\sigma_D=\gamma\sigma_I$, $\sigma_I=1.5$ and $\gamma=0.7$
   (b) points with large corner response ($R(A_W) > t$, where t = 1% of the maximum observed $R(A_W)$ value)
   (c) local maxima of $R(A_W)$ from previous step (using a 3x3 neighborhood). To better visualize the corners detected, overlay them on the original image.

   Submit the following:
   - (hardcopy) a report describing your results; it must include the output mentioned above for each test image and a discussion of results and comparisons; for all figures provide captions with a brief description
   - (email) one ZIP file containing:
     - the source code files
     - a README file with instructions on how to compile and run the program

2. (50 pts) Harris-Laplace Interest Point Detector

   Implement the Harris-Laplace interest point detector by following the steps discussed in class. Here is an outline of the main steps; for more details, look at the lecture slides and [Mikolajczyk04]. You will be using a DoG Scale Space to approximate the Laplacian of Gaussian (LoG) Scale Space.



(a) Generate a Gaussian Scale Space (G_SS).

To create the G_SS, start from some initial scale σ_0 and iterate n times by increasing the scale by a factor k each time (i.e., σ_0, $k\sigma_0$, $k^2\sigma_0$, …, $k^n\sigma_0$). Use $\sigma_0=1.5$, $k=1.2$, and $n=17$; for simplicity, do not perform sub-sampling.

(b) Generate a Difference-of-Gaussian Scale Space (DoG_SS).

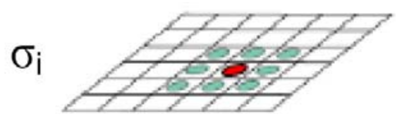
Based on the G_SS, build the DoG_SS by subtracting adjacent levels in G_SS.

(c) At each level of the G_SS, extract interest points using the Harris corner detector.

Using the Harris corner detector, compute a set of interest points (corners) at each level of the G_SS. Note that the Harris detector also applies smoothing when computing the derivatives. Therefore, you should not apply the Harris detector on the G_SS images because you will be smoothing twice. Instead, to compute the Harris corners at level m, apply the Harris corner detector on the original image using $\sigma_D=\gamma\sigma_I$, $\sigma_I=k^m\sigma_0$, $\sigma_0=1.5$, and $\gamma=0.7$

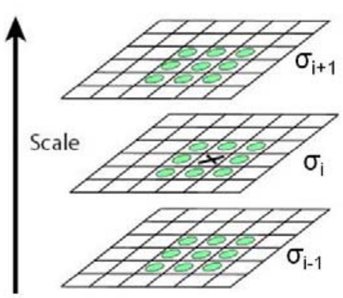
(d) Perform non-maxima suppression separately at each scale to find the strongest corners.

For each interest point detected in the previous step, determine whether it corresponds to a local extremum (local max or min) by comparing its $R(A_W)$ value to the $R(A_W)$ values of its eight neighbors (using a 3x3 window) as shown in the figure below. Reject corners which do not correspond to a local extremum or their $R(A_W)$ value is less than a threshold t_1 (in the literature, $t_1=1500$ has been used but you may need to experiment more with it).



(e) Perform non-maxima suppression along scales to find most stable corners and extract their characteristic scale.

For each interest point detected in the previous step, determine whether it corresponds to a local extremum by comparing its DoG value to the DoG values of its eight neighbors at the same scale as well as the nine neighbors at the scale above and the nine neighbors at the scale below (26 neighbors) as shown in the figure below. Reject corners which do not correspond to local maxima or their DoG value is less than a threshold t_2 (in the literature, $t_2=10$ has been used but you may need to experiment more with it).



For visualization, show each interest point using a distinctive symbol (e.g., a cross) along with its spatial extent (characteristic scale) using a circle of radius $r=2\sigma$ where σ is the scale (level) at which the interest point was detected. The interest points should be shown on the original image.

Submit the following:

- (hardcopy) a report describing your results using all the “Boat” and “Graf” images; it must show the interest points detected after steps (c), (d) and (e); choose just two of the scale levels for illustration; in each case, report the number of interest points found; a discussion of results and comparisons; for all figures provide captions with a brief description
- (email) one ZIP file containing:
  - the source code files
  - a README file with instructions on how to compile and run the program

3. (10 pts – mandatory for graduate students, optional as extra credit for undergraduate students)

   Following the previous problem, estimate how well the detected corners match between images in each of the “Boat” and “Graf” folders. Use the transformation matrix (homography) provided for different pairs of images to map one image onto another.

   A homography is a 3x3 matrix H which relates the pixel coordinates in the two images: $P_a = H P_b$. When applied to every pixel the new image is a warped version of the original image. Two images are related by a homography if both images are viewing the same plane from a different angle.

   Consider that two points P_a and P_b correspond (match) if the error $\|P_a - H P_b\| < 1.5$ pixels. Using this measure, compute the repeatability rate between images 1-3, and 1-5 in each of the “Boat” and “Graf” folders.

   Submit the following:

   - (hardcopy) a report describing your results; it must include for each pair of images mentioned above: the original two images and the warped second image, all with detected interest points, and the repeatability rate; a discussion of results and comparisons; for all figures provide captions with a brief description
   - (email) one ZIP file containing:
     - the source code files in C/C++
     - a README file with instructions on how to compile and run the program