UMBC
CMSC 491/691 Computer Vision

Homework 2
100 points

Due: March 15, 2024 23:59 Eastern

Answer all problems according to the instructions provided.
Written problems may be typeset or handwritten.
Submit one `.zip` file named `LastName_FirstName_hw2.zip` containing a single `pdf` named `hw2.pdf` with the answers to both the written and coding sections. The pdf **must** contain relevant code snippets, outputs and results, and other requested information for each task. Put all other files (code, data, outputs, etc.) in a single directory named "`code`"

1 Harris Corner Detection (45)

In this task, you will write code to **detect** features using the Harris Corner recipe. Refer to the lecture slides and references and follow the steps for Harris Corner Detector.

Task 1. *H-matrix compuation* 15 points
For each point in the image, consider a window of pixels around that point. Compute the 2×2 Harris matrix H for (the window around) that point,

$$
\begin{aligned}
H &= \sum_p w_p \nabla I_p (\nabla I_p)^\top \\
&= \sum_p w_p \begin{pmatrix} I_{x_p}^2 & I_{x_p} I_{y_p} \\ I_{x_p} I_{y_p} & I_{y_p}^2 \end{pmatrix} \\
&= \sum_p \begin{pmatrix} w_p I_{x_p}^2 & w_p I_{x_p} I_{y_p} \\ w_p I_{x_p} I_{y_p} & w_p I_{y_p}^2 \end{pmatrix} \\
&= \begin{pmatrix} \sum_p w_p I_{x_p}^2 & \sum_p w_p I_{x_p} I_{y_p} \\ \sum_p w_p I_{x_p} I_{y_p} & \sum_p w_p I_{y_p}^2 \end{pmatrix}
\end{aligned}
$$

where the summation is over all pixels p in the window, I_{x_p} is the derivative of the image at point p, the notation is similar for the y derivative. You should use the 3x3 Sobel operator to compute the x, y derivatives (extrapolate pixels outside the image with reflection). The weights w_p should be circularly symmetric (for rotation invariance) - use a 5x5 Gaussian mask with 0.5 sigma (or you may set Gaussian mask values more than 4 sigma from the mean to zero. This is within tolerance.). Use reflection for gradient values outside of the image range.

Task 2 *Corner Strength Function* 5 points
Use H to compute the corner strength function, $c(H)$, at every pixel.

$$c(H) = det(H) - 0.1(trace(H))^2$$

Task 3 *Orientation at each pixel* 5 points
Compute the approximate orientation as the angle of the gradient. The zero angle points to the right and positive angles are counter-clockwise.

Task 4 *Thresholding* 5 points
We will select the strongest keypoints (according to c(H)) which are local maxima in a 7×7 neighborhood.

Task 5 *Display the keypoints* 5 points
Visualize the keypoints for the three images provided (`harris_car, harris_elephant, harris_sunflower`) by displaying circles at the keypoint locations using `cv2.circle` function.

Task 6 *Different Corner Strength Function* 5 points
Instead of the corner strength function given in Task 2, choose another function, write the equation for it, and repeat Task 3, 4, 5. Show the results side by side with the ones from Task 5. Comment on the differences between the detections for the two versions of $c(H)$. *Note: you can use any of the other corner strength functions we discussed in class (see class slides).*

Task 6 *Visual inspection* 5 points
Collect one image each for the same objects (car, elephant, sunflower). Detect and visualize the keypoints for your images. How do they compare with the keypoints for the provided images for the same objects? Are similar features detected as keypoints? Comment on the differences and similarities and why.

2 In-Class Videos (55)

We watched the following videos in class:

- Katie Bouman: How to take a picture of a black hole:
  https://www.youtube.com/watch?v=BIvezCVcsYs
- Alyosha Efros: Why Computer Vision is Hard:
  https://youtu.be/YOKPo-I6cgs?si=Lju88payCEWyCs-N
- Jitendra Malik on "Three R's of Computer Vision":
  https://youtu.be/Q9uuDxMp_jU?si=Gil1RPNwwdHZNtBV
- Joseph Redmon: Computers can see. Now what?
  https://youtu.be/XS2UWYuh5u0?si=BIF4AuEKvlj4Hg94
- Shari Liu: Origins of social intelligence in human infants:
  https://youtu.be/MxBjtvYytpo?si=pkn8PCUTz7kyVRH9

For **each** of these talks/lectures/interviews, follow the prompts below and submit your responses:

1. Summarize the video in a couple of paragraphs. You can write about the big-picture topic and specific projects (tasks, methods, results, etc.) *(5 points)*
2. What was your favorite part of the talk / discussion? *(2 points)*
3. Cite and summarize (in one paragraph) one of the speaker's published papers discussed in / relevant to the video. *(4 points)*