Assignment 1

CS5370: Deep Learning for Vision/AI5100: Deep Learning/AI2100: Deep Learning
IIT-Hyderabad
Jan-Apr 2021

Max Marks: 50
Due: 4th Feb 2021 11:59 pm

Instructions

- Please use Google Classroom to upload your submission by the deadline mentioned above. Your submission should comprise of a single ZIP file, named `<Your_Roll_No>_Assign1`, with all your solutions, including code.
- For late submissions, 10% is deducted for each day (including weekend) late after an assignment is due. Note that each student begins the course with 10 grace days for late submission of assignments, of which upto 4 grace days can be used for a single assignment. Late submissions will automatically use your grace days balance, if you have any left. You can see your balance on the Marks and Grace Days document, soon to be shared under the course Google drive.
- You have to use PYTHON for the programming questions.
- Please read the department plagiarism policy. Do not engage in any form of cheating - strict penalties will be imposed for both givers and takers. Please talk to instructor or TA if you have concerns.

1 Theory (15 marks)

You can submit your response as a PDF document, which can be typed out in LaTeX/Word, or handwritten and scanned. If handwritten, please ensure legibility of answers.

1. **Linear Filters (2+2+2+1+3=10 marks):** In class, we introduced 2D discrete space convolution. Consider an input image $I[i, j]$ and a filter $F[i, j]$. The 2D convolution $F * I$ is defined as

$$(F * I)[i, j] = \sum_{k,l} I[i - k, j - l]F[k, l] \tag{1}$$

   (a) Convolve the following I and F (using pen and paper). Assume we use zero-padding where necessary.

$$I = \begin{bmatrix} 2 & 0 & 1 \\ 1 & -1 & 2 \end{bmatrix} F = \begin{bmatrix} 1 & -1 \\ 1 & -1 \end{bmatrix} \tag{2}$$

   Please DO NOT write programs. It will also be helpful for answering question (d).

   (b) Note that the F given in Equation 2 is separable, that is, it can be written as a product of two filters: $F = F_1F_2$. Find F_1 and F_2. Then, compute $(F_1 * I)$ and $F_2 * (F_1 * I)$, i.e., first perform 1D convolution on each column, followed by another 1D convolution on each row. (Please DO NOT write programs. Do it by hand.)

(c) Prove that for any separable filter $F = F_1 F_2$
$F * I = F_2 * (F_1 * I)$
Hint: Expand Equation 1 directly.

(d) Carefully count the exact number of multiplications (multiplications only, including those multiplications due to zero-padding) involved in part (a) and part (b). which one of these requires fewer operations? You may find the computation steps you wrote down for (a) and (b) helpful here.

(e) Consider a more general case: I is an $M_1 \times N_1$ image , and F is an $M_2 \times N_2$ separable filter.

i. How many multiplications do you need to do a direct 2D convolution?

ii. How many multiplications do you need to do 1D convolution on rows and columns?
Hint: For (i) and (ii), we are asking for two functions of M_1, N_1, M_2 and N_2 here, no approximations.

iii. Use Big-O notation to argue which one is more efficient in general: direct 2D convolution or two successive 1D convolutions?

2. **Canny Edge Detector (2.5+2.5=5 marks):** Suppose the Canny edge detector successfully detects an edge. The detected edge (shown as the red horizontal line in Figure 2a) is then rotated by θ, where the relationship between a point on the original edge (x, y) and a point on the rotated edge (x', y') is defined as

$$x' = xcos\theta \ ; \ y' = ysin\theta$$

(a) Will the rotated edge be detected using the same Canny edge detector? Provide either a mathematical proof or a counter example. *Hint:* The detection of an edge by the Canny edge detector depends only on the magnitude of its derivative. The derivative at point (x,y) is determined by its components along the x and y directions. Think about how these magnitudes have changed because of the rotation.

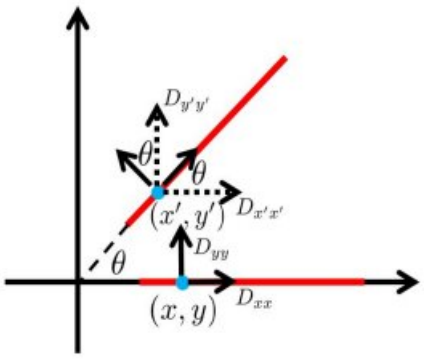

Figure 1: Canny Edge Detector

(b) After running the Canny edge detector on an image, you notice that long edges are broken into short segments separated by gaps. In addition, some spurious edges appear. For each of the two thresholds (low and high) used in hysteresis thresholding, state how you would adjust the threshold (up and down) to address both problems. Assume that a setting exists for the two thresholds that produce the desired result.

2 Programming (35 marks)

- Please see the attached zip file which contains 6 programming question in **DL4V_Assignment_1.ipynb** notebook. Do fill out the code where-ever it is asked for and turn-in the completed jupyter notebook.
- Marks breakdown is as follows:
  - Question 1: 10 marks
  - Question 2: 5 marks
  - Question 3: 2.5 marks
  - Question 4: 2.5 marks
  - Question 5: 10 marks
  - Question 6: 5 marks
- Note: you are required to work with images provided in the zip file. Specifically, **car_road.jpg** and **car.jpg** for Question 1 and **clown.png** for rest of the questions.