Homework 2

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AuE 8930: Machine Perception and Intelligence

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* Refer to Syllabus for homework grading, submission and plagiarism policies;
* Submission files includes (Due March. 6, 2020 11:59 pm):

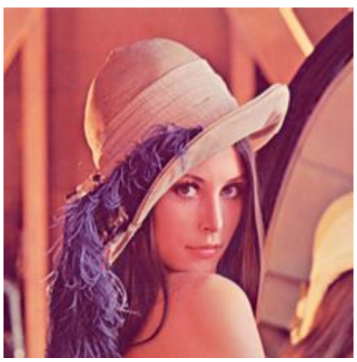
- This document file (with answers), and with your program results/visualization;
- A .zip file of source code (and data if any) with names indicating question number;

Note: For questions 1) and 2), you are required to write your own code rather than using any direct build-in implementation from 3rd party (like Matlab, Python, or others) libraries. You may use 3rd party built-in functions to check your results if you would like.

Question 1)

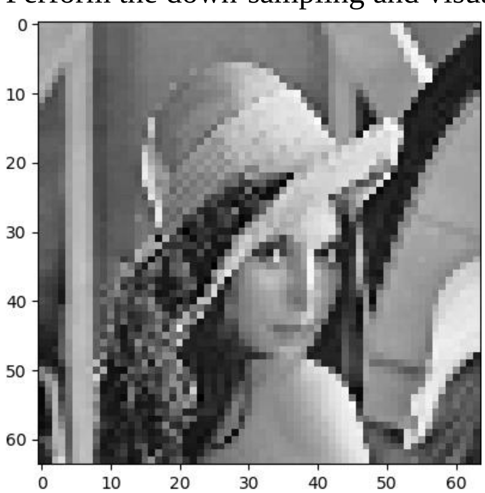
[Sampling/2D-Convolution – 15 pts] Download the image "Lenna.jpg" from the hyperlink. (Lenna or Lena image is a standard test image widely used for image processing since 1973.)

1-1) Convert the image from RGB to gray, using a standard RGB-intensity conversion approach like NTSC, and store the converted image "LennaGray.jpg" as an 8-bit gray image. (2 pts)



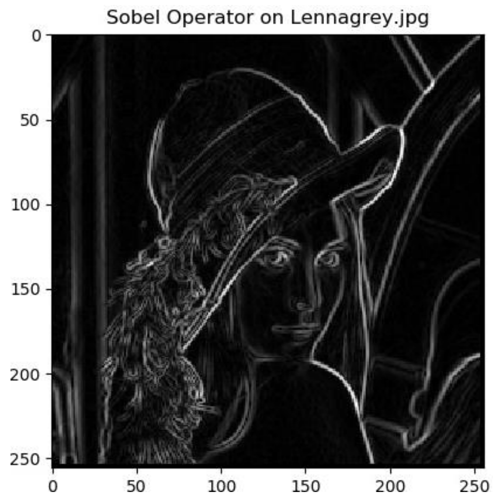
Lenna grey scale image.jpg

1-2) Down-sampling image "LennaGray.jpg" from size 256x256 to 64x64. (3 pts)
Perform the down-sampling and visualize your result.




```
print('The gray scale w is:', w)
print('The gray scale h is:', h)

downscale = np.zeros(shape=(64,64))
for i in range(64):
    for j in range(64):
        downscale[i,j] = gray_img[i*4, j*4]
plt.figure(3)
plt.imshow(downscale, cmap = plt.get_cmap('gray'))
plt.savefig('downscaled_gray_scale.jpg')
plt.title('Lenna grey scale downscaled image.jpg')
```

1-3) Implement the convolution (using basic arithmetic operations only, rather than build-in conv()) of Sobel kernel on the “LennaGray.jpg” for edge detection, visualize and comment your detection result. (10 pts)

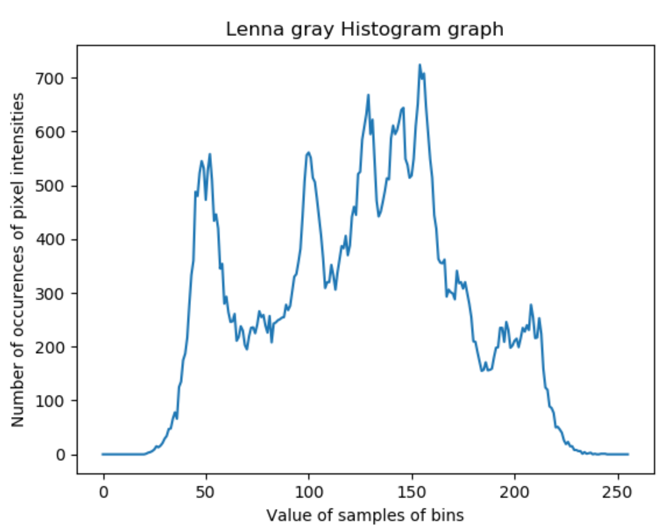



```python
for i in range(1, h - 1):
    for j in range(1, w - 1):
        horizontalGrad = (horizontal[0, 0] * gray_img[i - 1, j - 1]) + \
                         (horizontal[0, 1] * gray_img[i - 1, j]) + \
                         (horizontal[0, 2] * gray_img[i - 1, j + 1]) + \
                         (horizontal[1, 0] * gray_img[i, j - 1]) + \
                         (horizontal[1, 1] * gray_img[i, j]) + \
                         (horizontal[1, 2] * gray_img[i, j + 1]) + \
                         (horizontal[2, 0] * gray_img[i + 1, j - 1]) + \
                         (horizontal[2, 1] * gray_img[i + 1, j]) + \
                         (horizontal[2, 2] * gray_img[i + 1, j + 1])

        newhorizontalImage[i - 1, j - 1] = abs(horizontalGrad)

        verticalGrad = (vertical[0, 0] * gray_img[i - 1, j - 1]) + \
                       (vertical[0, 1] * gray_img[i - 1, j]) + \
                       (vertical[0, 2] * gray_img[i - 1, j + 1]) + \
                       (vertical[1, 0] * gray_img[i, j - 1]) + \
                       (vertical[1, 1] * gray_img[i, j]) + \
                       (vertical[1, 2] * gray_img[i, j + 1]) + \
                       (vertical[2, 0] * gray_img[i + 1, j - 1]) + \
                       (vertical[2, 1] * gray_img[i + 1, j]) + \
                       (vertical[2, 2] * gray_img[i + 1, j + 1])

        newverticalImage[i - 1, j - 1] = abs(verticalGrad)

        # Edge Magnitude
        mag = np.sqrt(pow(horizontalGrad, 2.0) + pow(verticalGrad, 2.0))
        newgradientImage[i - 1, j - 1] = mag
```

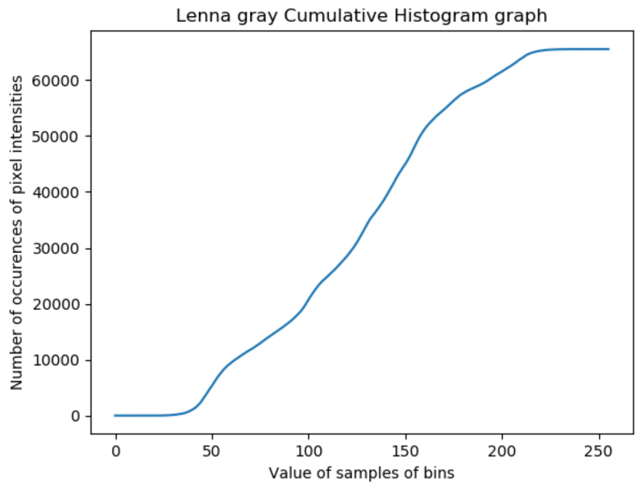
Question 2)

[Histogram Equalization – 15 pts.] Take the converted from above gray image “LennaGray.jpg”.

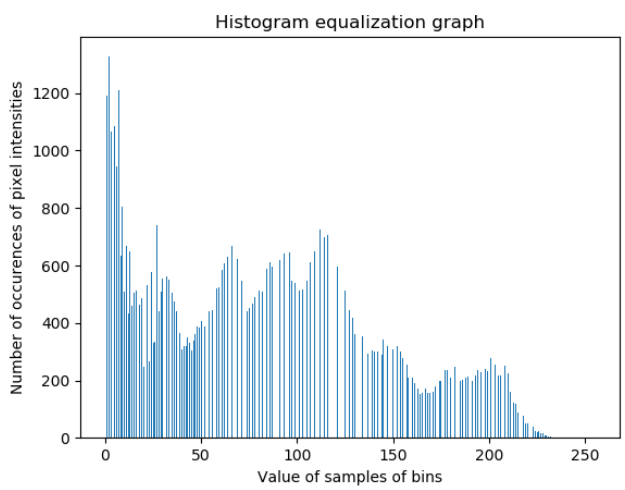
2-1) Perform histogram analysis and visualize histogram distribution (2 pts);



2-2) Calculate and visualize accumulative histogram distribution (3 pts);



2-3) Implement a function to perform histogram equalization for this image, visualize your histogram-equalized image and its histogram distribution. Comments the difference between the two images before/after histogram equalization. (10 pts);



Explanation:

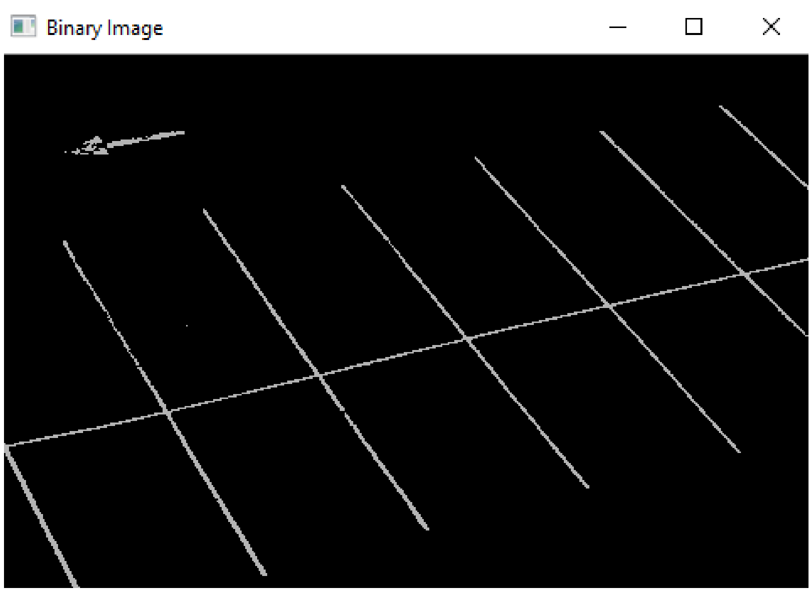
In the first method with histogram distribution, the intensities are distributed in the image and it represents the number of pixels for each of the intensity values which are considered. The histogram determines the number of pixels for each brightness level considering from the black and white to the color channels. Since, we work on the gray scale image of Lenna, the peaks are reached since the image has high brightness level in most of the pixels in the image. While considering the second image after performing the histogram equalization, the contrast present in the images are increased to a great extent. This is accomplished by effectively spreading out the most frequent intensity values which means the stretching of the intensity range present in the image. By doing histogram equalization, the global contrast of images increases when the data is represented by close contrast values. Moreover, the areas of lower local contrast help in gaining a higher contrast. From, the graph it can be observed that the intensity is equally spaced but has peaks in the first part of the image because of the sharp hair contrast lines in the image.

Question 3)

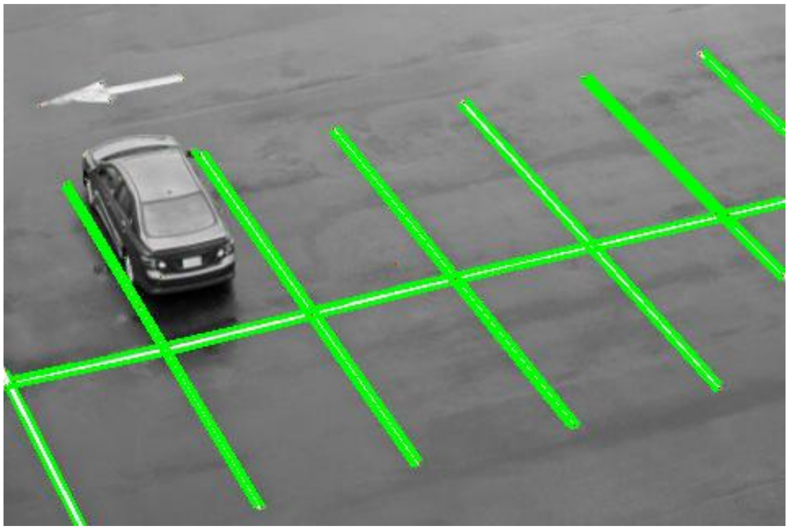
[Line Detection – 30 pts] Download the image "ParkingLot.jpg" from the hyperlink.

Note: For this question, you are free to use any 3rd party libraries.

3-1) Apply and visualize histogram analysis, then find a proper threshold to convert the image to a binary image. (2 pts)



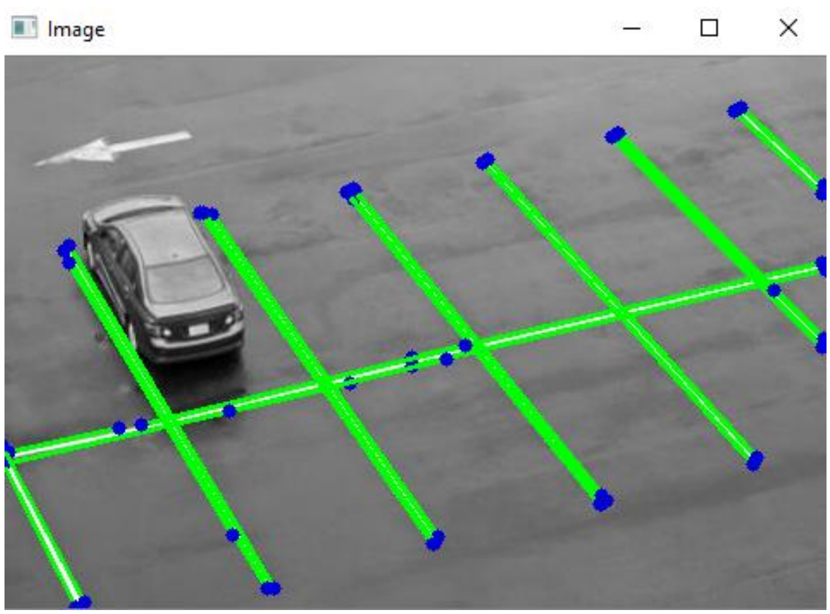
3-2) Apply Hough transformation or other line detection approach to detect multiple lines in the image (You select a threshold for the voting matrix). Visualize the lines in the image space and in the transformed space (like Polar space) respectively. (5 pts)



3-3) Comment on: will the two lines as two sides of a particular park space be parallel or not, explain why? (3 pts)

Generally, the two lines which represents the two sides of a parking space will be parallel. This is because, it allows with fitting more cars than usual and helps in creating addition space when the cars are not around. Moreover, this is also due to the lines which help in allocating a finite amount of space to the users for parking than parking without any concerns.

3-4) Design and implement the approaches to find all park space frames with the four vertex points of each frame. Describe your approaches and visualize all detected frames with different colors overlaid on the original image. The TA will check your code. (20 pts)



Question 4)

[Survey – 40 pts] Write a 2~3 pages survey report on a specific 2D-data measurement/detection problem related to automotive engineering (e.g.: lane detection, traffic sign detection, drivable area detection, a B-scan inspection for a manufacturing component, material characterization using microscopy image, et al. It is not limited to camera data. A negative example: 'Obstacle detection in 2D image' is not considered to be a specific problem because obstacle is not a specific target).

The grading of this question is based on the contents which the survey covers:

- The importance of this measurement (5);
- The challenges of measuring this target (5);
- Existing solutions of measuring this target (15);
- Existing problems of measuring this target (5);

There will be other grading factors (such as novelty, organization, et al) (10);

* You are encouraged to include any drawing/table in the report;

* Attention: use "…" [1] to cite any sentence you literally copied and use … [1] to cite a content you referred to, with reference list in the end;

Abstract:

The following research survey contains the lane and pavement marker detection using 2D LIDAR as prime sensor and cameras based on the fusion methodology. Lane-level map generation requires more details and therefore individual lanes must be correctly acquired using the accurate road line detection followed by appropriate parameterization. If the road is simple and has only a couple of lanes with no road signs on the ground other than the road lines, the generation of road-level map and a lane-level map will not be very different. In certain cases, like a complex boulevard in an urban area which has multiple lanes and various road signs mixed with road lines, it becomes a little difficult to detect the lanes accurately. During such circumstances, fast and accurate road line detection becomes an important issue in lane-level map generation.

The importance of 2D LIDAR measurement for lane detection:

The 2-dimensional scanning LIDAR is importantly used for detecting the lane mark and pavement mark by processing the LIDAR range and reflectivity data. In general, two-dimensional localization and mapping is famous with the 2D LIDARs and seen in wheeled robots and ground vehicles. It works on the assumption that the motion of the LIDAR is two dimensional and that the measurements have been collected at a consistent height. Since, 2D LIDAR helps in performing the detection and ranging tasks on the surfaces, it is highly important to rely on the LIDARs for lane detection. Moreover, the LIDAR data will be useful when detecting the road lanes within a certain distance or a perimeter. The remaining LIDAR data apart from the data from this perimeter are neglected. The LIDAR data point carries intensity value as well as its location depending upon the reflexibility of the scanned surface on the roads. Therefore, the points or lines of the road marks can be easily categorized from the points of the drivable region using the intensity. The LIDAR data also helps in distinguishing the road lines from the points categorized as road marks. The 2D LIDAR data also helps in identifying the correct road lines because the difference between certain road lines, arrows and stop signs can be perceived through the 2D LIDAR data. The 2D LIDAR only requires one laser beam since it will help in pulsing based on the spin movement and collect horizontal distance to the target to get data on the X and Y axes respectively.

Figure 1: Road marking detection

The challenges of measuring this target:

Generally, 2D LIDARs does not have enough range for detection and perception. Also, the LIDAR data needs robustness and it comes down to vibration and shock, wear, tear and cleaning. The research works have proven that by detecting the road lines of the simple roads having at most two lanes with few road signs on the ground. With the intersection of multiple roads, the detection of one road lane becomes mixed up with the other. Although, there are solutions to this, with the fusion mechanisms with cameras, it becomes even more difficult for relying on the 2D LIDAR for accurate lane detection and pavement marker detection. The method for lane detection is done with 2D LIDAR for detecting the pavement and lanes and not for the lane keep assist. This because of the challenges that arise due constant data dependency on the 2D LIDAR which sometimes may not be feasible. The heavy weather conditions also affect the 2D LIDAR data with more noise and inaccurate readings.

Existing solutions of measuring this target:

Sensor fusion of a stereo camera and 2D LIDAR for lane detection: [1]

This is a research work on a lane detection algorithm based on the fusion of a camera and 2D LIDAR data. The images from the cameras are taken into input as bird's eye view images and the locations of objects and lanes are detected by LIDAR. The camera data here are given as a binary format to the bird view image as in case of the lane detection. Here the proposed algorithm is as follows:

1. Get the camera data (Bird View Image) and 2D LIDAR data points.
2. Segment the 2D LIDAR data to identify the groups and objects present.
3. Map the identified groups and objects to the Bird View Image.
4. Turn pixels of groups and objects into background on the Bird View Image.
5. Apply lane detection to the modified Bird View Image.

Also, it is mandatory to reduce the noise from a binary bird view image for detailed accuracy and precision in the measured signals. The lane detection is performed with the canny edge detection and symmetrical local thresholding (SLT) for clear representation of the edges. The number of correctly detected lanes is the number of lanes where the specified distance limit is greater than the distance computed by each defined metric and all the lanes represent all the ground truth lanes. Thus, relatively accurate information is retrieved from both the cameras and the 2D LIDAR.

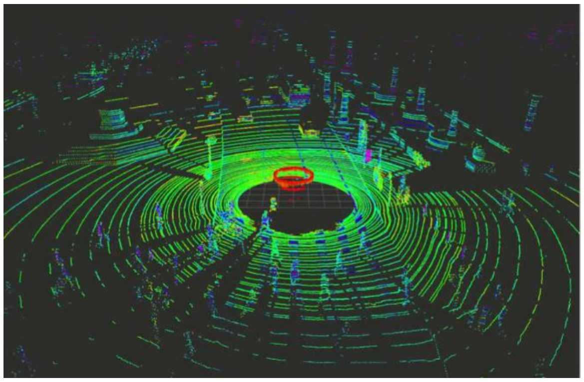


Figure 2 Point cloud 2D for lane detection

Real-time road lane detection in urban areas using LIDAR data: [2]

The main motive of this research work is to provide a detection algorithm for raised road lanes using a 2D LIDAR. The result of this algorithm is viewed in both the highways and urban scenarios. However, if a lane-level map is provided to the vehicle, the path planning process would become considerably simpler and safer so that the vehicle would be obligated to be equipped with sensors. To detect the road lines out of various road marks having similar LIDAR intensities, search was made for a set of parallel lines separated by the interval of the lane width [3]. The lane width distance was set as 3.4 meters, but the value was updated during the detection process for the lanes. Finally, the lane-level digital map is generated for the lane detection with respect to the moving vehicle at any instant.

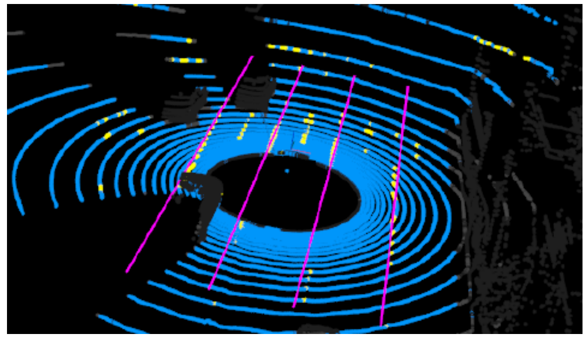


Figure 3 Lane detection with algorithm

Lane markings and road registration:

If the road points are segmented, the 2D LIDAR intensity is used to extract marking points. The extraction process differs depending upon the intensity threshold and the high reflectivity determines the stemming from road markings. The grid reflectivity data is transformed to a 2D intensity image to which lane detection can also be performed by using Hough transform.

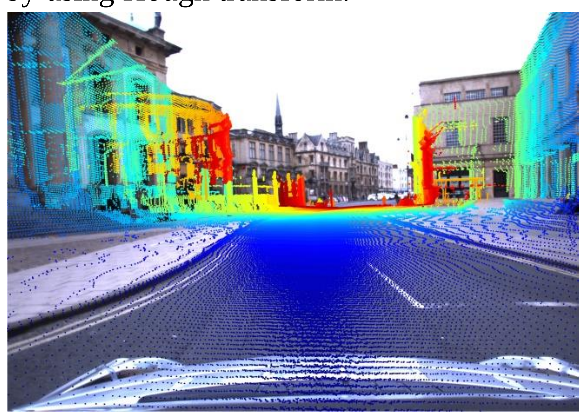


Figure 4 Camera and 2D LIDAR fusion

Existing problems of measuring this target:

There are multiple problems faced while measuring the lane in roads and they are as follows:

Uncertainty:

The uncertainty sums up the range of values within which the value of the measure falls within a specified level of confidence. 2D LIDAR uncertainty sometimes leads to misleading data and proper calibration must be made to avoid this error.

Measurement accuracy:

It is a concept that relates to whether there is bias or any change in the measurements. This is indeed different from precision which means the variation among the set of observations. On a broader perspective, it is impossible to have measurements that are very precise but inaccurate and very imprecise but accurate. There can also be problems due to the snow fall in certain conditions and in certain places. This will lead to relatively less accuracy in the results.

Weather conditions:

The weather conditions greatly affect the 2D LIDAR measurement of the lanes since the error rate increases with the heavy rain and fog conditions. This creates a problem when in situation where there are multiple lanes and a need is there for detecting one lane to travel.

References

[1] K. W. S. Yasin YENİAYDIN, "IEEE Explore," [Online]. Available: https://ieeexplore.ieee.org/document/8806579.

[2] J. J. a. S. H. Bae. [Online]. Available: https://www.mdpi.com/2079-9292/7/11/276/pdf.

[3] J. S. T.-H. (. L. a. D. L. Tran Tuan Nguyen∗, "IEEE Explore," [Online]. Available: https://ieeexplore.ieee.org/document/7313471.