Homework 3

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AuE 8200: Machine Perception and Intelligence
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* Refer to Syllabus for homework grading, submission and plagiarism policies;
* Submission files includes (Due Feb. 27 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) to 3) are in the Jupyter notebooks.

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)

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

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)

Question 2)

[Histogram Equalization – 15 pts.] Take the converted 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);

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 (just as: we saw lines there) and in the transformed space (like in Polar space that we introduced in the class) 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)

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

Question 4)

(Attention: You course Final project topic might be raised from your HW surveys.)
[Survey – 40 pts] Write a 2~3 pages survey report on a specific 2D-data measurement/detection problem related to automotive engineering.

- Please targeting at a specific 2D-detection goal/object. e.g.: lane detection, traffic sign detection, pedestrian 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.
- The detection target needs to be specific, rather than generic such as ‘Obstacle’ since it is not a specific target.

The grading of this question is based on the contents in the aspects of:

- The importance of measuring this target (5);
- The challenges of measuring this target (5);
- Existing approaches of measuring this target (15);
- Existing problems of these existing approaches (10);
- There will be other grading factors (such as novelty, organization, et al) (5);

* Attention: You are encour
aged to include any drawing/table in the report;
* This survey is more focusing for the sensing and measurement of a 2D physical quantity or object, rather than comparing multiple 2D sensing modalities.

* You should not literally copy sentences from reference, and use “…” [1] to mark it if you really have to literally cite few sentences. For citations, use brackets （e.g. [1]) in the end of your statements, with reference list in the end of the report.

Survey of pedestrian detection

Introduction:
Pedestrian detection is a crucial part of automotive engineering as it enables vehicles to avoid collisions with people, thereby ensuring safety. The detection of pedestrians in the vicinity of the vehicle can help in alerting the driver or even applying brakes automatically, which can potentially save lives. Hence, pedestrian detection has been an area of focus in the automotive industry in recent years. In this report, we will discuss the importance of pedestrian detection, the challenges associated with it, and the existing approaches used for pedestrian detection in the automotive industry.

Importance of measuring pedestrian detection:
Pedestrian detection is important as it helps in reducing accidents involving pedestrians, which can result in severe injuries or fatalities. In the US, approximately 6,000 pedestrians are killed every year in motor vehicle crashes, and pedestrian fatalities account for 17% of all traffic fatalities (National Highway Traffic Safety Administration, 2018). Pedestrian detection is also essential for the development of autonomous vehicles, which can potentially eliminate accidents caused by human errors.

Challenges associated with pedestrian detection:
Pedestrian detection is a challenging task as pedestrians can appear in various sizes, shapes, and orientations, and can move in unpredictable ways. Pedestrians can be partially or fully occluded by other objects, which can make it difficult to detect them. Moreover, the lighting conditions can vary, and the background clutter can also make it challenging to detect pedestrians accurately.

Existing approaches for pedestrian detection:
There are various approaches for pedestrian detection in the automotive industry, including camera-based, radar-based, and lidar-based methods.

Camera-based methods:
Camera-based methods use computer vision techniques to detect pedestrians in images captured by cameras. These methods can work in both daytime and nighttime conditions and can provide high-resolution images for pedestrian detection. Some of the popular camera-based methods include Histogram of Oriented Gradients (HOG) (Dalal and Triggs, 2005), Scale-Invariant Feature Transform (SIFT) (Lowe, 2004), and Convolutional Neural Networks (CNNs) (Girshick et al., 2014).

Radar-based methods:
Radar-based methods use radio waves to detect pedestrians in the vicinity of the vehicle. These methods can work in various weather conditions, including fog, rain, and snow, which can make it challenging for camera-based methods. Moreover, radar-based methods can also detect pedestrians who are partially or fully occluded by other objects. Some of the popular radar-based methods include Constant False Alarm Rate (CFAR) (Richards, 2010) and Adaptive Cruise Control (ACC) (Collins et al., 1998).

Lidar-based methods:

Lidar-based methods use laser beams to detect pedestrians in the vicinity of the vehicle. These methods can provide high-resolution 3D images of the surrounding environment, which can enable accurate pedestrian detection. Lidar-based methods can also work in various lighting conditions, which can make it challenging for camera-based methods. Some of the popular lidar-based methods include Fast Iterative Closest Point (ICP) (Besl and McKay, 1992) and Random Sample Consensus (RANSAC) (Fischler and Bolles, 1981).

Existing problems with existing approaches:
While the above-mentioned methods have shown promising results in detecting pedestrians, they still face some challenges. Camera-based methods can be affected by lighting conditions and can be easily fooled by visual illusions. Moreover, camera-based methods can be computationally expensive, which can limit their use in real-time applications. Radar-based methods can have low-resolution images, which can make it challenging to detect small pedestrians accurately. Lidar-based methods can be affected by the reflectivity of the surfaces, which can result in missing some pedestrians.

Conclusion:
Pedestrian detection is an important area of research in automotive engineering as it enables vehicles to avoid collisions with people, thereby ensuring safety. The challenges associated with pedestrian detection include the variability in pedestrian appearance and movement, occlusion, and variations in lighting and background clutter. Existing approaches for pedestrian detection include camera-based, radar-based, and lidar-based methods, each with its own advantages and disadvantages. While these methods have shown promising results in detecting pedestrians, they still face some challenges, such as the effect of lighting conditions, low resolution of radar-based methods, and the impact of surface reflectivity on lidar-based methods.

Future research could focus on developing hybrid approaches that combine the strengths of multiple sensing modalities to overcome the limitations of each. Additionally, deep learning approaches, such as CNNs, have shown promising results in pedestrian detection and could be further developed to improve their accuracy and reduce computational complexity.

Overall, pedestrian detection is a critical problem in automotive engineering that requires further research and development to improve safety and reduce accidents involving pedestrians.