AER 1515: Perception for Robotics

Homework 3

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Section 1 Depth Estimation

In section 1, I used the code from assignment 2 to determine the depth. The first step was to read the disparity map, then read the calibration info. After, I read the depth and assign a value of 0 if the disparity map was 0. Using the equation $z = \frac{f*B}{disp}$, I was able to assign a depth. If the depth was over 80meters or under 0.1m, those values were assigned a depth of 0. Then the map was saved in the folder "estimated depth". Underneath is a figure illustrating most of the code used.

```
    # Calculate depth (z = f*B/disp)
    depth_map = np.zeros_like(disparity_map)
    #loop through each values in depth map

    for i in range(disparity_map.shape[0]):
        for j in range(disparity_map.shape[1]):
            # Assign depth of 0 if disparity map is 0
            if disparity_map[i][j] == 0:
                depth = 0
            else:
                # Recall depth (z = f*B/disp)
                depth = stereo_calib.f*stereo_calib.baseline / disparity_map[i][j]

                # Discard pixels past 80m
                # Assign depth of 0 if pixel is greater than 80 m or less than 10 cm
                if depth > 80 or depth < 0.1:
                    depth = 0
            depth_map[i][j] = depth

    # Save depth map
    cv.imwrite(f"{output_dir}/{sample_name}.png", depth_map)
```

Figure 1 Depth Estimation

Section 2 2D Bounding Box Estimation

In this section, using YOLOv3, we determined bounding box for cars by tuning the confidence and non-maximum suppression thresholds. Originally, different values for the threshold and confidence threshold were used to find the best accuracy by comparing it to the ground truth Figure 2. However, testing some of the results that had "good accuracy" were not giving good results when opening the images. Multiple bounding boxes were found on the same image Figure 3.

```
The average accuracy was 0.8599917441606522 and 1 bounding box was missed for threshold = 0.1 and confidence threshold = 0.1
The average accuracy was 0.8599917441606522 and 1 bounding box was missed for threshold = 0.25 and confidence threshold = 0.1
The average accuracy was 0.8083558614764895 and 1 bounding box was missed for threshold = 0.5 and confidence threshold = 0.1
The average accuracy was 0.7246212657127116 and 0 bounding box was missed for threshold = 0.75 and confidence threshold = 0.1
The average accuracy was 0.7228017600431834 and 0 bounding box was missed for threshold = 0.9 and confidence threshold = 0.1
The average accuracy was 0.8961367491218779 and 1 bounding box was missed for threshold = 0.1 and confidence threshold = 0.25
The average accuracy was 0.8961367491218779 and 1 bounding box was missed for threshold = 0.25 and confidence threshold = 0.25
The average accuracy was 0.8383045718073845 and 1 bounding box was missed for threshold = 0.5 and confidence threshold = 0.25
The average accuracy was 0.7393423974514007 and 0 bounding box was missed for threshold = 0.75 and confidence threshold = 0.25
The average accuracy was 0.7443991431168148 and 0 bounding box was missed for threshold = 0.9 and confidence threshold = 0.25
The average accuracy was 0.9237758412080652 and 1 bounding box was missed for threshold = 0.1 and confidence threshold = 0.5
The average accuracy was 0.9237758412080652 and 1 bounding box was missed for threshold = 0.25 and confidence threshold = 0.5
The average accuracy was 0.9237758412080652 and 1 bounding box was missed for threshold = 0.5 and confidence threshold = 0.5
The average accuracy was 0.8364493537832189 and 1 bounding box was missed for threshold = 0.75 and confidence threshold = 0.5
The average accuracy was 0.8320983350276947 and 0 bounding box was missed for threshold = 0.9 and confidence threshold = 0.5
The average accuracy was 0.9237758412080652 and 1 bounding box was missed for threshold = 0.1 and confidence threshold = 0.75
The average accuracy was 0.9237758412080652 and 1 bounding box was missed for threshold = 0.25 and confidence threshold = 0.75
The average accuracy was 0.9237758412080652 and 1 bounding box was missed for threshold = 0.5 and confidence threshold = 0.75
The average accuracy was 0.9181291282176971 and 1 bounding box was missed for threshold = 0.75 and confidence threshold = 0.75
The average accuracy was 0.903789127156848 and 0 bounding box was missed for threshold = 0.9 and confidence threshold = 0.75
The average accuracy was 0.9572889713140634 and 5 bounding box was missed for threshold = 0.1 and confidence threshold = 0.9
The average accuracy was 0.9572889713140634 and 5 bounding box was missed for threshold = 0.25 and confidence threshold = 0.9
The average accuracy was 0.9572889713140634 and 5 bounding box was missed for threshold = 0.5 and confidence threshold = 0.9
The average accuracy was 0.9505862514177958 and 4 bounding box was missed for threshold = 0.75 and confidence threshold = 0.9
The average accuracy was 0.9500586346343711 and 1 bounding box was missed for threshold = 0.9 and confidence threshold = 0.9
```

Figure 2 Accuracy for different thresholds and confidence thresholds

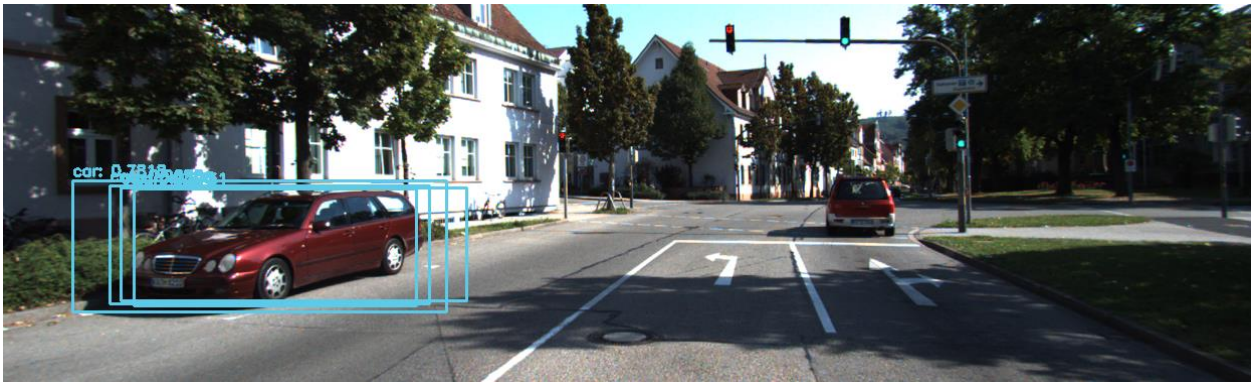

Figure 3 Bad Results Bounding Boxes

After manually testing different thresholds, the one that gave the best results was a **confidence of 0.5 and a non-maximum suppression threshold of 0.5**. Using those values, the following were the results of the test set.

Figure 4 Bounding Box Test Image 1

Figure 5 Bounding Box Test Image 2

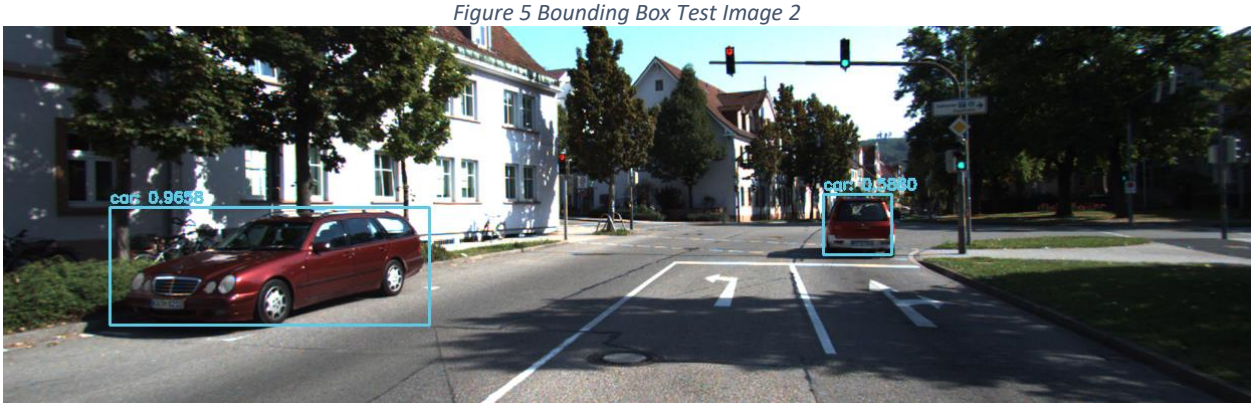

Figure 6 Bounding Box Test Image 3

Figure 7 Bounding Box Test Image 4

Figure 8 Bounding Box Test Image 5

Section 3 Instance Segmentation

In question 3, we got the segmentation images of the training set and the testing set. The following are the results of the segmentation for the training set and testing set. The thresholds chosen was a maximum distance threshold of 10, and a cropping_val of 0.05 (make bounding box 0.05% smaller, gave better results)

Figure 9 Segmentation Test Image 1

Figure 10 Segmentation Test Image 2

Figure 11 Segmentation Test Image 3

Figure 12 Segmentation Test Image 4

Figure 13 Segmentation Test Image 5

Figure 14 Segmentation Training Image 1

Figure 15 Segmentation Training Image 2

Figure 16 Segmentation Training Image 3

Figure 17 Segmentation Training Image 4

Figure 18 Segmentation Training Image 5

Figure 19 Segmentation Training Image 6

Figure 20 Segmentation Training Image 7

Figure 21 Segmentation Training Image 8

Figure 22 Segmentation Training Image 9

Figure 23 Segmentation Training Image 10

In question 3, we implemented segmentation using the following method. First, we get the depth math. Then we create a segmentation mask and set all the values to 255 (car). Then we get the box area found in the previous question and calculate the average depth of that box. It is to note that I cropped the box slightly before calculating the average and it gave better results (bounding box multiplied by a cropping ratio). Then going pixel by pixel in the car bounding box, we compare it to the average depth found. If the distance between the pixel and the average depth is higher than a certain threshold, we assume that it is not the car and we set that value to 0.

For question three, we looped through many different cropping ratio and distance threshold to get the best precision and recall. It is to note that the precision and recall was calculated by the following equations:

$$Precision = \frac{True\ Positive}{True\ Positive + False\ Positive}$$

$$Recall = \frac{True\ Positive}{True\ Positive + False\ Negative}$$

The following is the raw output of average precision and recall for each measured tried can be found in the appendix. Looking at it, the best values was a maximum distance of 10 when comparing the pixels to the average depth and cropping by 0.05%. Those values gave a precision score of 89% and a recall score of 83%.

Appendix

```
Testing crop value of 0.05 and distance threshold of 1
The results for a cropping value of 0.05 and a distance threshold of 1 is:
There was 4 boxes that had under 75% precision and 10 boxes under 75% for recall
The average precision is 0.6821694634159059 and the average recall is 0.16843585596689775

Testing crop value of 0.05 and distance threshold of 2.5
The results for a cropping value of 0.05 and a distance threshold of 2.5 is:
There was 3 boxes that had under 75% precision and 7 boxes under 75% for recall
The average precision is 0.7893072449357753 and the average recall is 0.45706775650306974

Testing crop value of 0.05 and distance threshold of 5
The results for a cropping value of 0.05 and a distance threshold of 5 is:
There was 1 boxes that had under 75% precision and 3 boxes under 75% for recall
The average precision is 0.8711702080667966 and the average recall is 0.7320845406740013

Testing crop value of 0.05 and distance threshold of 7.5
The results for a cropping value of 0.05 and a distance threshold of 7.5 is:
There was 0 boxes that had under 75% precision and 2 boxes under 75% for recall
The average precision is 0.8933661738750331 and the average recall is 0.8275911938652495

Testing crop value of 0.05 and distance threshold of 10
The results for a cropping value of 0.05 and a distance threshold of 10 is:
There was 0 boxes that had under 75% precision and 2 boxes under 75% for recall
The average precision is 0.8901460933354247 and the average recall is 0.8336957660448817

Testing crop value of 0.1 and distance threshold of 1
The results for a cropping value of 0.1 and a distance threshold of 1 is:
There was 2 boxes that had under 75% precision and 10 boxes under 75% for recall
The average precision is 0.9227026917685045 and the average recall is 0.18846431199659436

Testing crop value of 0.1 and distance threshold of 2.5
The results for a cropping value of 0.1 and a distance threshold of 2.5 is:
There was 1 boxes that had under 75% precision and 8 boxes under 75% for recall
The average precision is 0.9276892815057742 and the average recall is 0.5343760063455728

Testing crop value of 0.1 and distance threshold of 5
The results for a cropping value of 0.1 and a distance threshold of 5 is:
There was 0 boxes that had under 75% precision and 8 boxes under 75% for recall
The average precision is 0.9432902326183589 and the average recall is 0.6880395316072787

Testing crop value of 0.1 and distance threshold of 7.5
The results for a cropping value of 0.1 and a distance threshold of 7.5 is:
There was 0 boxes that had under 75% precision and 8 boxes under 75% for recall
The average precision is 0.9433404728209913 and the average recall is 0.7076366787228516
```

Figure 24 Average Precision and Recall for different measures (Part 1)

```
Testing crop value of 0.1 and distance threshold of 10
The results for a cropping value of 0.1 and a distance threshold of 10 is:
There was 0 boxes that had under 75% precision and 8 boxes under 75% for recall
The average precision is 0.9409663528339228 and the average recall is 0.7157951041835109

Testing crop value of 0.15 and distance threshold of 1
The results for a cropping value of 0.15 and a distance threshold of 1 is:
There was 0 boxes that had under 75% precision and 10 boxes under 75% for recall
The average precision is 0.9801268350537476 and the average recall is 0.2468528498953157

Testing crop value of 0.15 and distance threshold of 2.5
The results for a cropping value of 0.15 and a distance threshold of 2.5 is:
There was 0 boxes that had under 75% precision and 10 boxes under 75% for recall
The average precision is 0.9736241444822236 and the average recall is 0.44723572809116574

Testing crop value of 0.15 and distance threshold of 5
The results for a cropping value of 0.15 and a distance threshold of 5 is:
There was 0 boxes that had under 75% precision and 10 boxes under 75% for recall
The average precision is 0.9795179538779291 and the average recall is 0.5499690593686266

Testing crop value of 0.15 and distance threshold of 7.5
The results for a cropping value of 0.15 and a distance threshold of 7.5 is:
There was 0 boxes that had under 75% precision and 10 boxes under 75% for recall
The average precision is 0.9772129232678527 and the average recall is 0.5657701705543403

Testing crop value of 0.15 and distance threshold of 10
The results for a cropping value of 0.15 and a distance threshold of 10 is:
There was 0 boxes that had under 75% precision and 10 boxes under 75% for recall
The average precision is 0.9763906098589741 and the average recall is 0.5763905070185664
```

Figure 25 Average Precision and Recall for different measures (Part 2)