TDS3651
VISUAL INFORMATION PROCESSING

Assignment 1:

To design an algorithm that returns the value of all the coins in an image.

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1. ABSTRACT

The proposed algorithm contains 4 parts, which are RGB and HSV image processing for preprocessing part, image subtraction, and watershed segmentation.

a. RGB image processing involves canny edge detection, morphological operation, contour finding, contour drawing and flood filling.

b. HSV image processing involves mean shift filtering before HSV image conversion, saturation layer extraction, image thresholding on saturation layer, operation to represent white (coin) as foreground and black as background, contour finding, circle drawing, flood filling and morphological operation.

c. Image subtraction involves subtraction of resulting image processed from (a) and (b).

d. Watershed segmentation is used for segments detection and segments counting to enable circle drawing and area calculation.

2. INTRODUCTION

To detect the number of coins in an image, image segmentation is one of the popular ways. Before that, some preprocessing tasks must be done. The loaded image is processed using two separated ways.

In the first part, Canny edge detector, a stable and consistent segmentation method is used to get the edges for all coins in a particular image. Then, morphological operation is applied using dilation followed by erosion to get better edge. The image is then flood filled to get filled coins for further processing.

In the second part, mean shift is used for initial step for segmentation to obtain smoother image. The image is then converted into HSV format and saturation layer (S) is extracted. Image thresholding is applied to S to segment out gold coins. For some cases, silver coins are segmented out along with gold coins (explained in result analysis). Circles are drawn on each of the segments and are flood filled. Morphological operation using erosion followed by dilation is used for noise reduction and removal.

Image subtraction is applied on the image in first and second part to get old coins, though for some cases, the result may not be so accurate: some gold coins are remained on the subtracted image (explained in result analysis).

Watershed segmentation is used to count the number of segments, draw the final circle on the input image for area calculation and visualization purpose. The value of coins is calculated using the range of area calculated.

3. DESCRIPTION OF METHODS

Before calculating the area of the coins in the image, some preprocessing tasks are needed to aid in obtaining better results. The loaded image is always converted into RGB color space for ease of displaying and visualizing. The preprocessing tasks are separated into two part and one doesn't affect another. First part is to obtain the segments for all coins while second part is to obtain the segments for gold coins. For Part 3, the final image obtain from the first part will be subtracted with the image from the second part. This will obtain silver coins. Part 4 will be using watershed segmentation to identify number of segments found in input images and find the contour for each segment, draw the circles and calculate area and value of coins.

3.1 Part 1: RGB image processing

The purpose of this part is to acquire all segments of coins in the input image. Canny edge detector is used to obtain the edges of every coins inside a particular image. The reason of using Canny edge detector is because every coin in the image have strong gradient and hence their edges can be identified effectively.

Original Image

Image After Using Canny Edge Detector

Then, morphological operations which leaded by dilation and followed by erosion is applied to the edge detected. Dilation is applied first to expand the connected edges and then erosion is to trim the edges so that the edges of coins are rounder. Both operation used 2 iterations for best result. The kernel size used for both dilation and erosion is relatively small which is 3x3 of array with ones so that the amount to expand and trim can be controlled easily.

Image After Morphological Operation

The next step is finding the contour of the edges and draw the contour to make the outermost edge connected, forming round shape.

Contour Drawn On Image After Morphological Operation

Morphological operation is applied again with same sequence, number of iterations and kernel size since the outermost edge for some coins are not connected after drawing the contours. Then, flood fill the all the connected edges to obtain a filled round shape which are almost same shape with the original coins' shape. By using these steps, every coin with different contrast and saturation can be segmented and represented clearly in binary form.

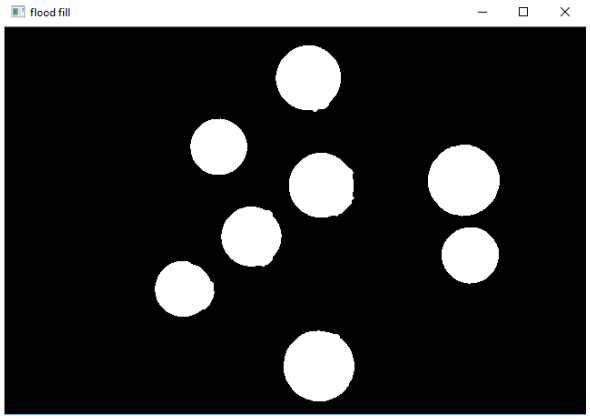


Image After Flood Filling

3.2 Part 2: HSV image processing

The purpose of this part is to obtain segments of gold coins in the image. First of all, mean shift filtering is used to effectively smooth the surface of coins in the image. The mean shift filtering depends on two variable: spatial window radius and color window radius. The value of spatial window radius and color window radius are adjusted to 2 and 40 accordingly for the best result.

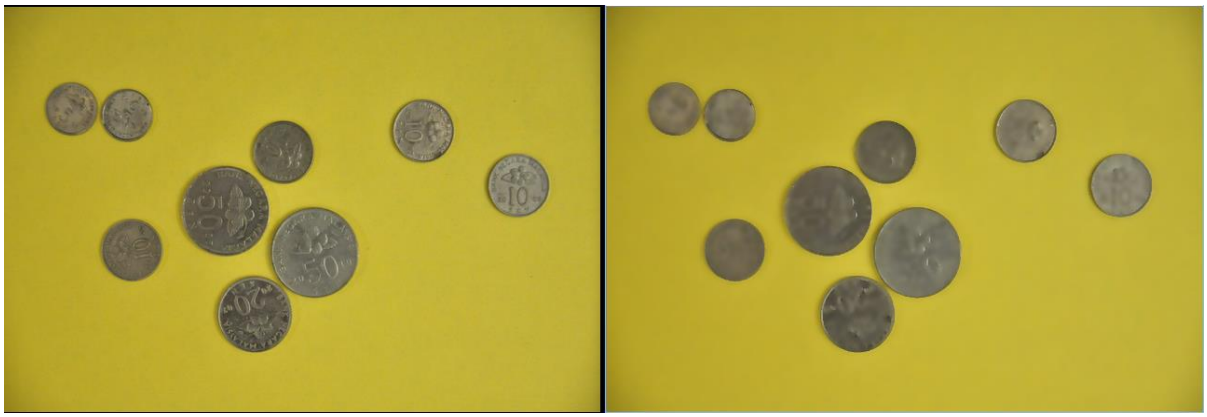
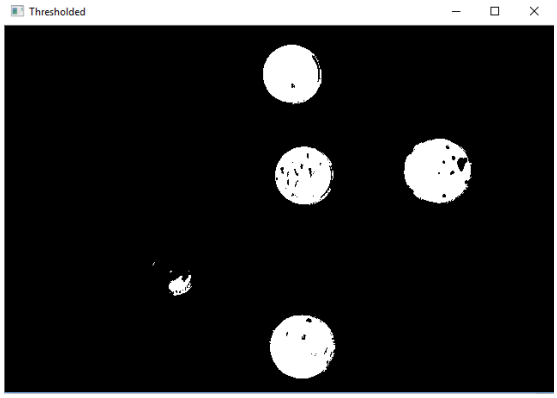


Image Before Mean Shift Filtering *Image After Mean Shift Filtering*

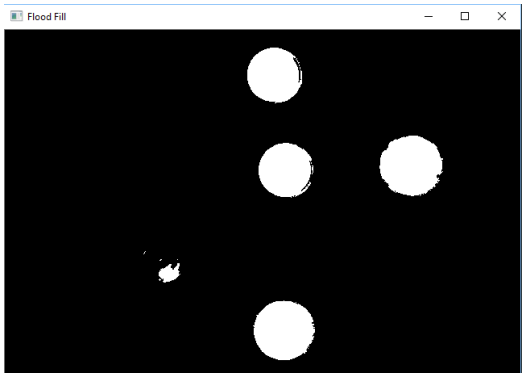
After that, the image is converted from RGB format into HSV format. Since gold coins will have higher saturation than silver coins which are darker, the saturation layer (S) from HSV image is extracted out and thresholding is applied onto it to get the segments of gold coins. For the case with all silver coins, their segments will be inside the threshold image, this case is explained in Result And Analysis.

Saturation Layer Of HSV Image

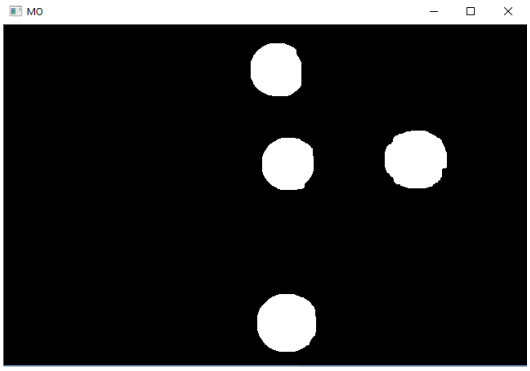


After Thresholding

The image after thresholding is checked and inverted if the foreground color is black to make the coins is always white in color and flood filling is applied to fill up all the small holes in the foreground. Then we apply erosion with 8 iterations wo remove all the small pieces of noise and dilation with 8 iterations to get back the original size of gold coins' segment.



After Flood Filling



After Morphological Operations

3.3 Part 3: Image subtraction

The resulting image from Part 1 and Part 2 is subtracted to obtain silver coins since Part 1 image contains all coins while Part 2 image contain gold coins. Absolute value is taken for all the pixels of subtracted image to make sure all the values are positive. Then erosion with 4 iterations is applied to remove noise and dilation with 4 iterations is used to fill up the hole and expand the segments caused by erosion.

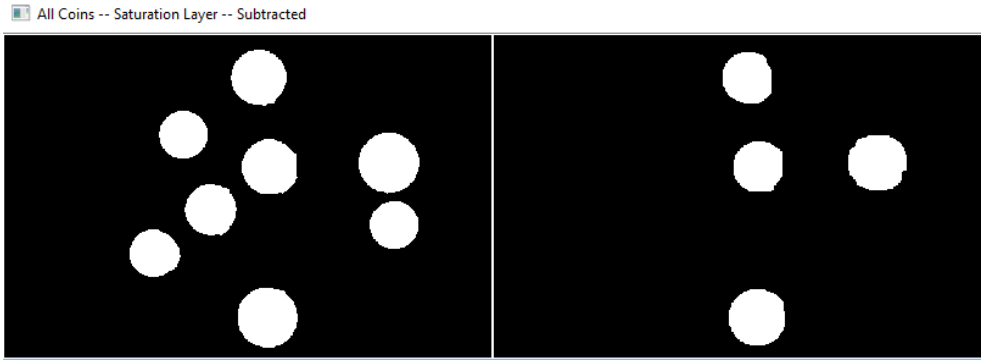
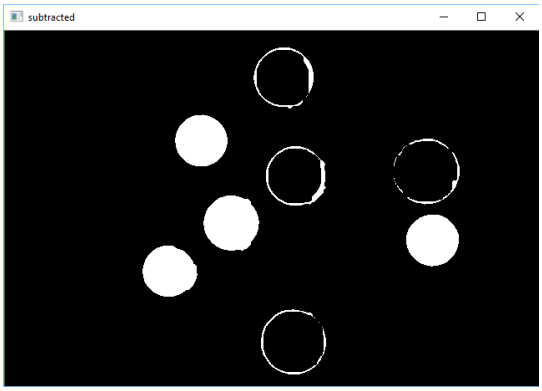
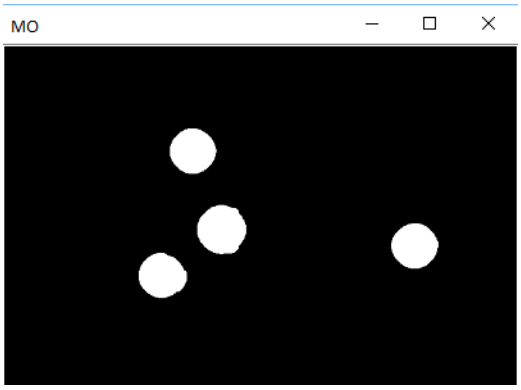


Image With All Coins *Saturation Layer of HSV*



After Image Subtraction



After Morphological Operation

3.4 Watershed segmentation and coins value calculation

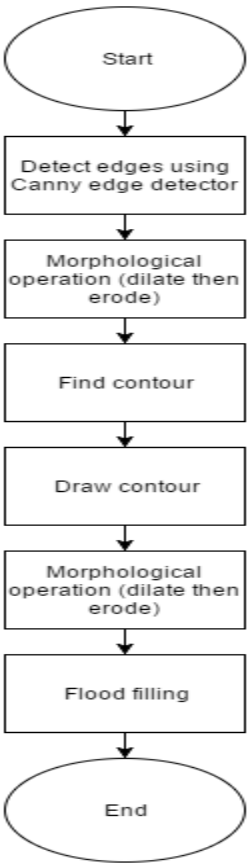
The input to watershed algorithm are image from Part 1, Part 2 and Part 3. The area calculation is described below:

1. We compare the number of segments between Part 1 image and Part 2 image, if the number of segments are the same, meaning that Part 1 and Part 2 images are having same properties of coins. In this case, Part 1 image will be used for area calculation.

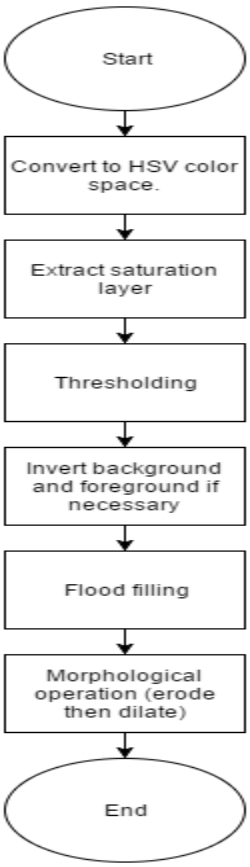
2. If the subtracted image contains segments, meaning that the coins in Part 3 image (subtracted image) are either mixed or silver coins. In this case, Part 2 image will be used for gold coins' area calculation and Part 3 image will be used for silver coins' area calculation.

Unique Segments Found In An Image ('g' for gold, 's' for silver)

The last step is defining two set of range of area for silver coins and gold coins. Since the size of old 5sen and 10sen is almost the same with the size of new 5sen and 10sen, their area can be calculated and classified into the same range. The value of coins is totaled up using the defined range.



Part 1



Part 2

4. RESULT AND ANALYSIS

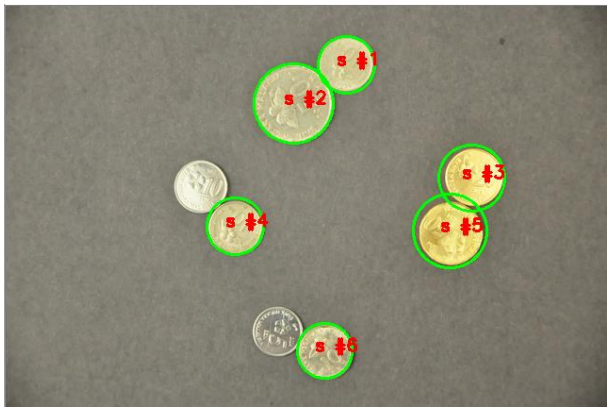
```
########  DETAILED RESULTS  ########
+-------+--------------+------------+--------------+
| Image | Accuracy Hit | Error (RM) | Run time (s) |
+-------+--------------+------------+--------------+
|   1   |      1       |    0.00    |    0.3020    |
|   2   |      1       |    0.00    |    0.6925    |
|   3   |      0       |    0.25    |    0.3502    |
|   4   |      1       |    0.00    |    0.3323    |
|   5   |      0       |    0.65    |    0.3352    |
|   6   |      1       |    0.00    |    0.2752    |
|   7   |      1       |    0.00    |    0.3428    |
|   8   |      1       |    0.00    |    0.2738    |
|   9   |      1       |    0.00    |    0.2667    |
|   10  |      0       |    0.30    |    0.3370    |
|       |              |            |              |
|  All  |      7       |    1.20    |    3.5077    |
+-------+--------------+------------+--------------+
```

Accuracy Hit and Error of coin values in COINSET 1.

Since the dataset contains coins with different combinations, some of them with all old coins, some of them with mixed old and new coins and some of them with all new coins. Besides that, new coins contain different colors, gold color for 20sen and 50sen while silver color for 10sen and 5sen. The size of 10sen and 5sen in new coins may have the same area due to effect of morphological operation. The contrast and saturation of every image also different from each other. These factors have affected the accuracy and error of the value of coins.

4.1 Problem 1: Mixed or Inverted Coins in Saturation Layer of HSV Image.

Saturation layer is assumed to contain only gold coins. When the saturation layer (S) from HSV images is extracted, some of them from COINSET 1 still contain silver coins because the saturation value of the silver coins is close to the saturation value of gold coins. Hence, when subtracting S with image contain all coins, the segments in subtracted image becomes mixed with gold and silver coins. This will cause some of the silver coins calculated using gold coins' area range while some of the gold coins calculated using silver coins' area range.




```
[INFO]Image 10
6 unique segments found in Saturation Layer

2 unique segments found in subtracted image
```

Saturation Layer is supposed to have only 2 unique segments which are gold coins but the image at left shown 6 unique segments due to saturation problem. (Mixed Coin)

There is another case where when the background is in gold color, the image after thresholding will contain only silver coins' segments and this lead to inaccurate result because the value of these silver coins will be calculated using gold coins' area range.

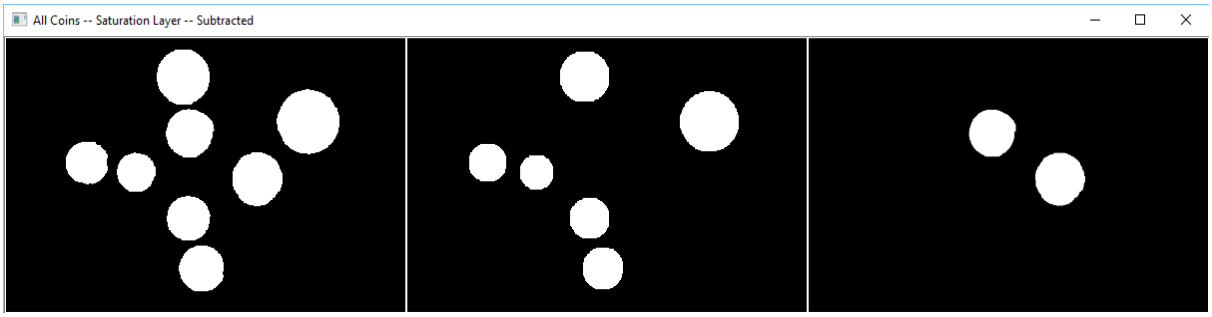
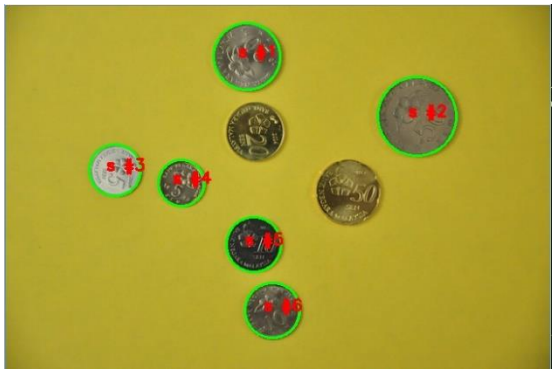


Image With All Coins *Saturation Layer Of HSV* *Subtracted Image*



```
[INFO]Image 3
6 unique segments found in Saturation Layer

2 unique segments found in subtracted image
```

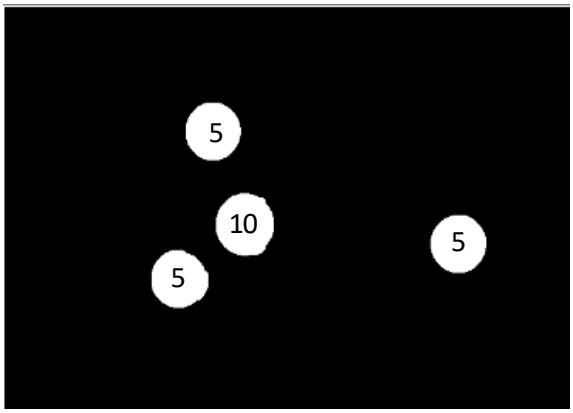
6 unique which are silver coins are found in Saturation Layer (Supposed to have only 2) → inverted result caused by background color.

4.2 Problem 2: Close Area between Different Value of Coins

When applying dilation and erosion, the area of coins will be affected such as:

1. 5sen and 10sen (no matter old coins or new coins)
2. 20sen and 50sen (for new coins)

Causing the area between them become almost the same. Hence, some of the 5sen will be treated as 10sen and some of the 20sen will be treated as 50sen and vice versa.



Close Area Between 5sen and 10sen Due To Dilation And Erosion

Furthermore, some of the coins have shadows and these shadows enlarge the area of coins when applying edge detection and thresholding, causing the inaccurate area calculation for the two cases above.

Changing Of Shape Caused By Shadow

Extra: COINSET 2

```
########  DETAILED RESULTS  ########
+-------+--------------+------------+--------------+
| Image | Accuracy Hit | Error (RM) | Run time (s) |
+-------+--------------+------------+--------------+
|   1   |      1       |    0.00    |    2.6380    |
|   2   |      1       |    0.00    |    0.6202    |
|   3   |      0       |    0.10    |    0.3398    |
|   4   |      0       |    0.10    |    0.3475    |
|   5   |      0       |    0.00    |    0.3471    |
|   6   |      0       |    0.30    |    0.3417    |
|   7   |      0       |    1.05    |    0.3345    |
|   8   |      0       |    0.35    |    0.3921    |
|   9   |      0       |    0.85    |    0.3408    |
|   10  |      0       |    0.50    |    0.3274    |
|       |              |            |              |
|  All  |      2       |    3.25    |    6.0290    |
+-------+--------------+------------+--------------+
```

Accuracy Hit and Error of coin values in COINSET 2.

5. SUGGESTION FOR IMPROVEMENTS

The root of the accuracy problem is caused by:

1. Similar saturation between old coins and new coins within a same image.
2. Background of the image caused inverted result in the saturation layer in HSV image. (supposed to have gold coins in saturation layer instead of silver coins).
3. Changing in original area due to morphological operation.
4. Changing in original area due to shadow of coins.

Furthermore, the value of the coins is determined by manually identify the area range for each coin and the images were captured from slightly different in height, therefore this algorithm which uses area to identify the value of coins is far not enough to acquire accurate result if the coin are captured from different high since the size of coins will differ according to distance from camera.

Possible suggestion for improvements:

1. Using color detection techniques to identify and segment out only gold coins in an image to make sure only gold coins are left in the saturation layer of HSV image to prevent mixed or inverted coins in the layer.
2. Using better improvement of kernel with different size or structure for morphological operations to avoid inconsistency in area.
3. Using deep learning techniques such as convolutional neural networks (CNN) which is a data driven approach to automatically classify the coins and identify their values.
    a. Provide input consists set of N images (in this case will be set of coins and background images), each labelled with one of K different classes and act as training set.
    b. Use the training set to learn what every one of the classes looks like.
    c. Evaluate the quality of the classifier by asking it to predict labels for a new set of images that it has never seen before, then compare the true labels of these images to the ones predicted by the classifier.