Santa Clara University

School of Engineering

Digital Image Processing I: Project Part 2

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1. Introduction

In this work we tries to get some insight of the different techniques used to identify features of objects in images, more specifically we will discuss the well know techniques of the Hough Transform and the more intuitive method of a Matching Filter. We first discuss the basic concepts behind the techniques, then we will take a look at some preliminary results using grayscale as well as color images, we will present some pre-processing methods and the effect these have in finding centers and radius of circular object.

1.1. Examples of the Test Images

In this work, the following images are examples of the images we use as test images and an example of preprocessing in order to do the separation between the background and foreground as well as the circular objects from non circular objects.

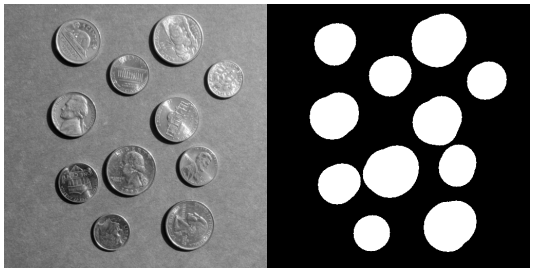


Figure 1.1 Example of grayscale image: only coins

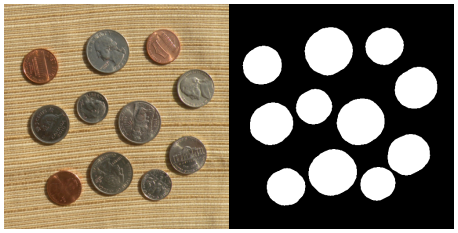


Figure 1.2 Example of color image: only coins

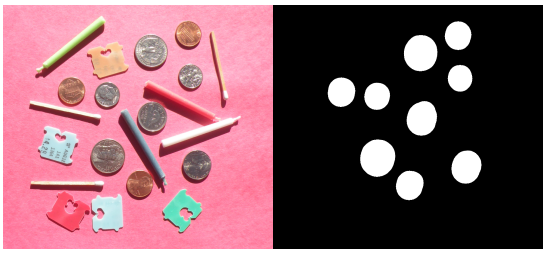


Figure 1.3 Example of color image: coins and non circular objects

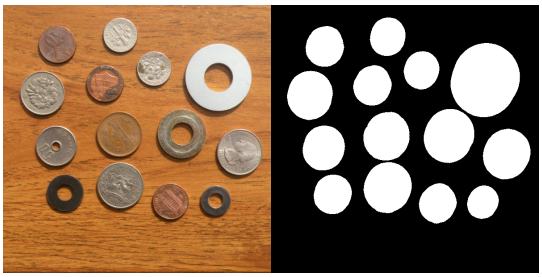


Figure 1.4 Example of color image: coins and circular objects

2. Response to Coins Objects

2.1. Matching Filter

2.1.1. Grayscale Images

To obtain these result first we obtained the templates from the original image, as seen in Figure 3.1.

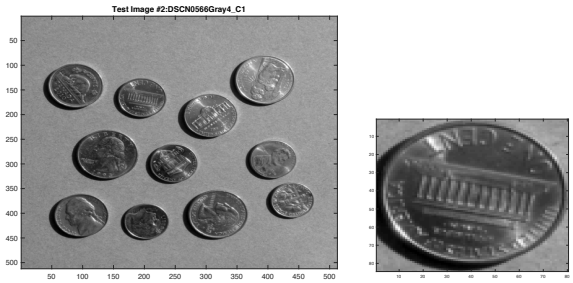


Figure 3.1 Image and example of coin template.

After getting the template from the original image we performed the normalized cross correlation and got the result shown in the left image in Figure 3.2.

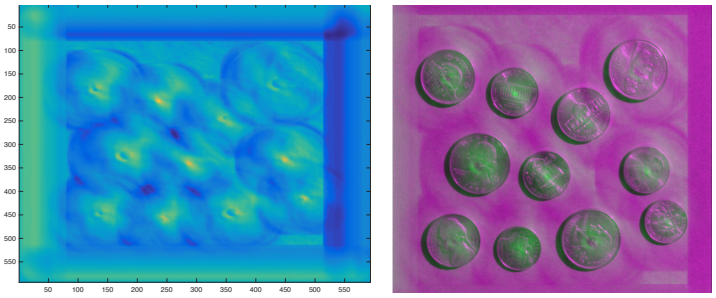


Figure 3.2 Cross correlation result

If we perform this operation for different templates we should be able to extract the locations of the peaks, which correspond to the location of the coins in the original, we can see this in the montage of the right image in Figure 3.2 where the three pennies have their peaks in the center.

2.1.2. Color Image

To perform the normalized cross correlation in Matlab, we need to have our images in a grayscale, therefore changing the color image to a grayscale and doing the same procedure as in section 3.1.1 we get the same result as before. The color information doesn't add helpful information and does not change the result we got before.

2.1.3. Preprocessing: Binary Segmentation

With the purpose of getting better results we perform a series of operation to the image to do a segmentation and try to separate the coins from the background and get the image shown in Figure 3.3.

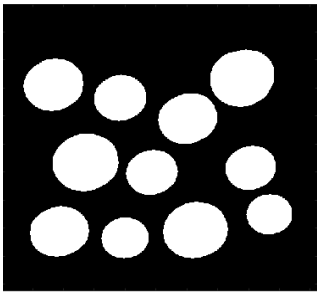


Figure 3.3. Segmented coin Image

To get the image in Figure 3.3 we first performed a two level thresholding followed by the morphological closing operation alongside the imfill function on Matlab, to fill the holes, and finally we performed an opening operation to remove noise and separate the white circles.

Then we performed the normalized cross correlation several times with different radius for our template element, we find the peaks, we remove the peak from the original BW image and repeated the process for all the range of R selected. Using Rmin = 78 and Rmax = 108, we got the result shown in Figure 3.4. Where we can see the identified centers in green.

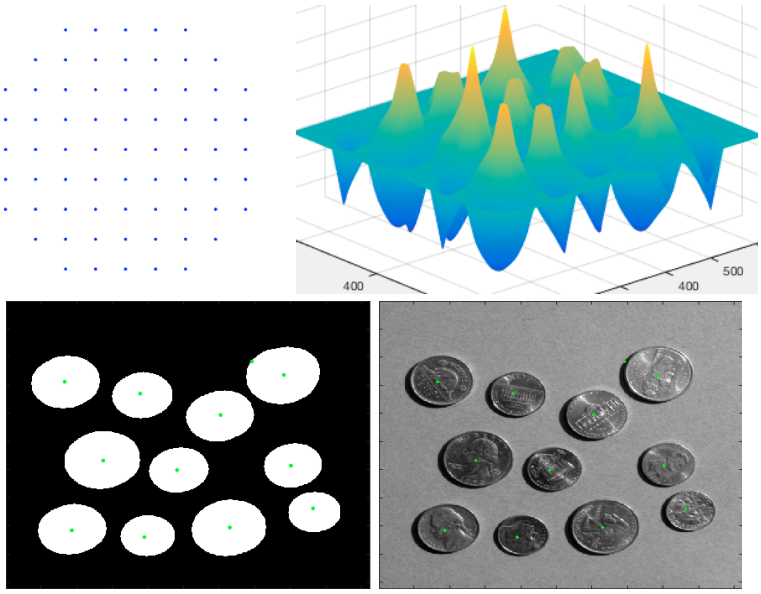


Figure 3.4 Results of the centers of coins from the cross correlation of a bw image.

In section 2.3 we summarized more results using Matching Filter, with images with only coins and images with distractors.

2.2. Hough Transform

2.2.1. Grayscale Image

To obtain these result we used the Matlab function called imfindcircle which in essence compute the general Hough Transform for circles for the input image and a range of radius to approximate the radius of the circles to found, as an output it returns the location of the center of the circles, and the approximate radiuses. [1]

First we open imtool to measure some radiuses in our image to use as an input for the imfindcircle function, as shown in Figure 3.5.

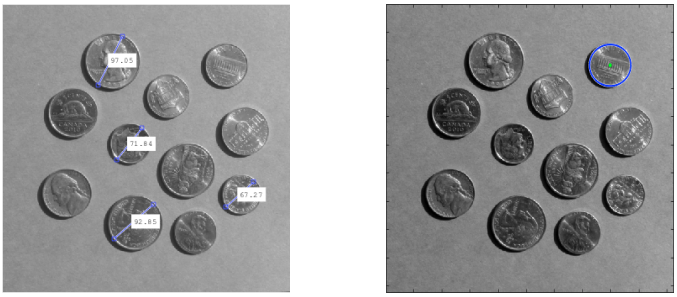
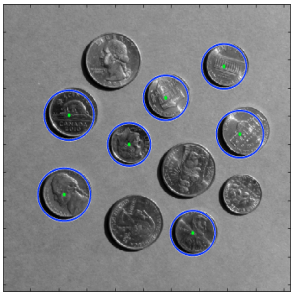


Figure 3.5 imtool and imfindcircle results

By default the functions tries to find bright circles in a black background, as most of the coins are darker than the background the function is not able to find the center of the coins. Trying again but this time telling the function to find dark circles in a bright background we get the result in figure 3.6.



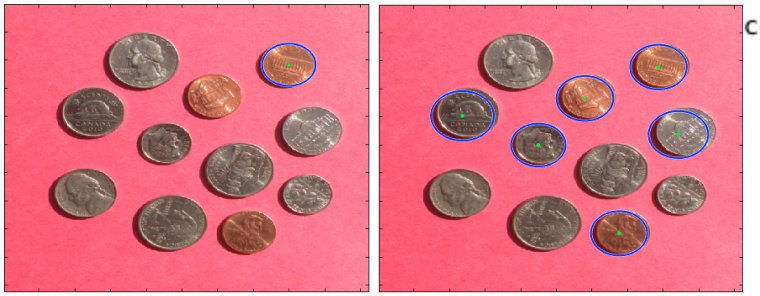
```
centers =

  393.3210  111.4769
  421.6783  231.8771
  224.7041  250.1458
  289.8408  167.3092
  337.9110  407.6309
  117.9449  198.3147
  109.3655  339.3388
```

Figure 3.6. imfilter trying to find dark circles in a bright background.

As we can see in Figure 3.6 the algorithms have better solution in this case.

2.2.2. Color Image

Performing the same procedure as in section 3.2.1 but in this case using the color version of the image we get the result shown in Figure 3.7



```
centers =

  393.4951  111.4224
  421.5283  231.6731
  117.9448  198.3383
  224.6865  250.2996
  290.0826  167.2976
  338.1234  407.7597
```

Figure 3.7 imfindcircles in a color image

As we can see we didn't obtain a big difference using the color images with respect the grayscale images. one posible workaround would be to play more with the setting of the function like the sensitivity but, we wanted to try as simple as possible in order to understand better the algorithm.

2.2.3. Preprocessing: Binary Segmentation

With the purpose of getting better results we will now perform a series of operation to the image to do a segmentation and try to separate the coins from the background. In doing so we get the bw image of figure 3.8.

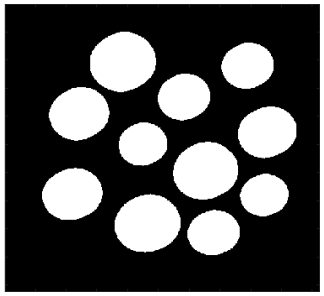


Figure 3.8. Segmented coin Image

To get the image in Figure 3.38 we first performed a two level thresholding in each of the color planes for the RGB image, for example for this particular image with a strong red background we were able to completely remove in the R plane, and then we combine the thresholded image in one, followed we performed a morphological closing operation alongside the imfill function on Matlab, to fill the holes, and finally we performed an opening operation to remove noise and separate the white circles.

Following the same procedure as in 3.2.1 we obtained the result shown in Figure 3.9.

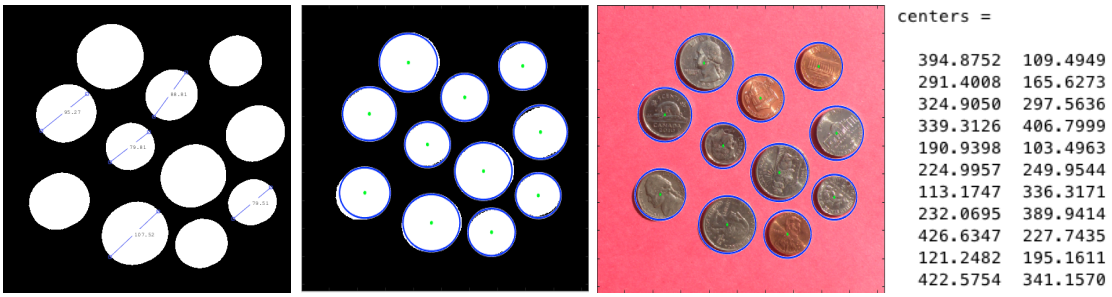
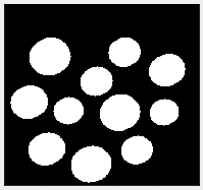
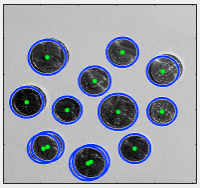
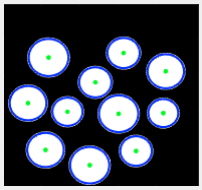
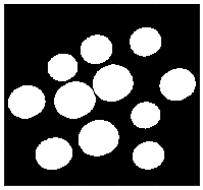
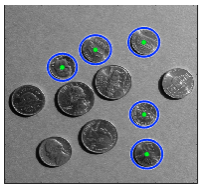
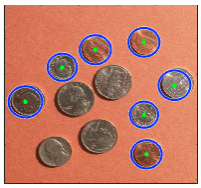
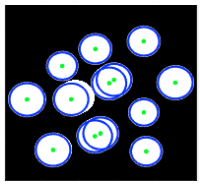


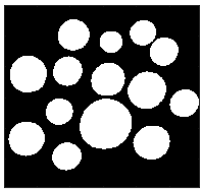
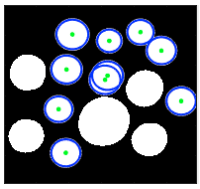
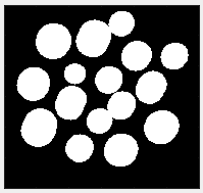
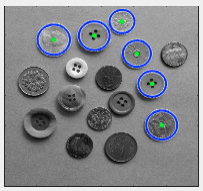
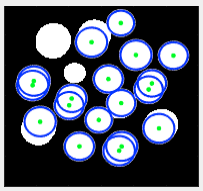
Figure 3.9 Results of the centers of coins from imfindcircles of a bw image.

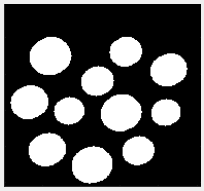
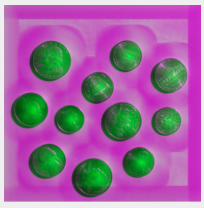
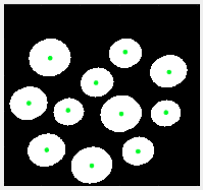
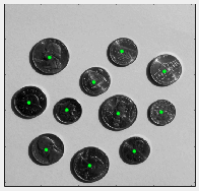
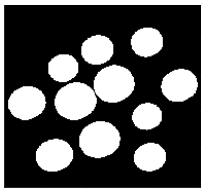
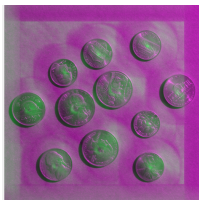
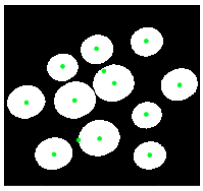
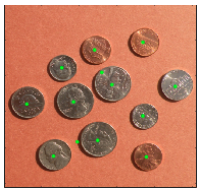
As we can see from the Figure 3.9 we obtained the approximation of the centers of all the coins present in the image.

In section 2.3 we summarized more results using the Hough Transform, with images with only coins and images with distractors.

2.3. Summary

Set	image	Image	Segmented Image	Best Hough Gray 'bright'/'dark'	Best Hough Color	Best Hough BW
1	3				-	
2	5					
3	4		-			-

4	5			None	None	
4	9					

Set	image	Image	Segmented Image	Best Matching Gray	Best Matching BW	Best Matching BW peaks
1	3					
2	5					
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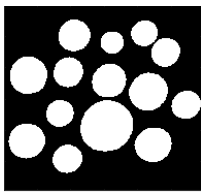
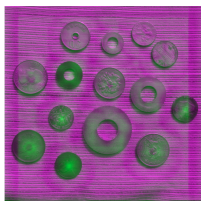
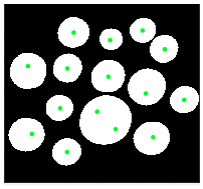
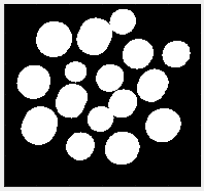
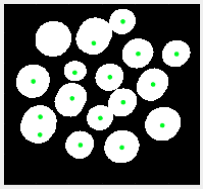
4	5					
4	9					

3. Plans for Improvement

As a plan for improvement, a more complex algorithm for searching the peaks values could be implemented, as well as to find a way to approximate the radius of the circles using matching filters. More complex and accurate preprocessing can be considered for each of the images, especially the ones with many distractors, such as adaptive thresholding using statistics or local pixel characterization methods, or color segmentation for the images to remove the shadows. We can also create a more interactive tool with more methods with the ability to create sequence of operations with the ability to return to a previous result and modify the next process, also with the ability to see the changes immediately and to develop some kind of KPI to quantitative measure the quality of the result.

4. Conclusions

1. Not every sequence of processes, or values, will work well for all images and to find all the centers of the coins whiting an image . Using images with the right condition, bright objects in dark background for example, taken specifically for the purpose that they will serve, considerably simplify the processing work thats needs to be done in the image and we get better result in less time.
2. We can use simple global image thresholding, to separate an image into two regions, background and foreground, but this process work get significantly better result if we can make use of the information in a color image, as we can separate the image in different planes and perform the thresholding in the different planes to later combine the images in only one.
3. In a color image we can use color segmentation in order to separate the different elements we are interest in, specially when we have to deal with shadows in our images, as we saw the accuracy of results in finding the centers of the coins gets deteriorated significantly.
4. Preforming the adequate kind of re processing to an image can significantly improve the final result, as we saw using the Hough Transform with a BW image instead of a color or grayscale image.
5. If we are working with images without the right conditions the process of finding good result becomes an interactive process, therefore if we want to process the images in an automatic way, more complex and intelligent algorithms needs to be implemented, e.g., deep neural networks.

5. References

1. https://www.mathworks.com/help/images/ref/imfindcircles.html
2. https://www.mathworks.com/help/images/ref/im2bw.html
3. https://www.mathworks.com/help/signal/ref/xcorr2.html
4. https://en.wikipedia.org/wiki/Template_matching