Lappeenranta-Lahti University of Technology LUT
School of Engineering Science
Computational Engineering
BM40A1201 Digital Imaging and Image Pre-Processing

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IMAGING MEASUREMENTS

Practical Assignment
xx.01.2023

ABSTRACT

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In this practical assignment the aim is to design and implement an image measurement setup which can estimate the number of presenting coins in the image. Image processing is carried out with intensity and geometric calibration, color transformation, binarizing, dilating and eroding, and finally shape recognizing. The measurement setup is tested with twelve different images, with different numbers and locations of coins. After parameter estimations, the numbers of each coin type in the images are recognized correctly for every test image, meaning that the implemented measurement setup reaches the theoretical accuracy of 100%.

CONTENTS

1 INTRODUCTION

1.1 The purpose of the coin detection with image based measurements

The purpose of this paper is to introduce an example system of how it's possible to detect Euro coins from an image, and how to classify them correctly. The coins taken in to consideration consists of 5 cent, 10 cent, 20 cent, 50 cent, 1 euro and 2 euro coins.

Detecting coins from images falls in to the tasks of measuring image objects and geometry. Because in addition to be able to recognise the shapes of the coins from the image, we also want to measure the coins sizes. The found coins and their calculated radii are compared to the standard coins sizes [1], and then classified to be one of them.

1.2 The design of measuring environment

The imaging setup consists of flat white surface with a checkerboard with known square sizes on top of it. For intensity calibration, we take many flat images of the surface and checkerboard. In addition to that, we take many bias and dark images with the same temperature and camera settings that will be used for the actual raw images.

The coins are placed on the surface separated from each other and the checkerboard. The imaging of the coins will be done overhead the coins, making sure that the light source for the camera is overhead as well which reduces the amount of shadows the coins will produce. For each of the images taken, the bias, dark and flat images will be used to calibrate the images intensity. The checkerboard then will be used to map the known distances of the squares to the pixels in the image.

2 METHODS

The image measurement processes are carried out with geometrical and intensity calibrations, gray scaling, edge detection, and MATLAB built in -functions utilizing more advanced image processing algorithms. The main reasoning behind the chosen methods is to calibrate and characterize the image so that the edges of coins (circles) can automatically be separated as clearly as possible from the background.

2.1 Geometric calibration

Geometric calibration for the measured image is done to map the coin sizes from millimeters to sizes in pixels. This is done by finding the first and second checkerboard corners locations, see figure 1, and calculating the euclidean distance (in pixels) between those points. This distance is equal to the width of the squares in the checkerboard. The real width for one of the squares is measured as $12.5\,mm$. Using both the real distance in millimeters and the measured distance in pixels, it's possible to calculate what is the width of a single pixel in the image by following the formula

$$pixel\ width = \frac{square\ width}{12.5} \frac{px}{mm}.$$

Using the pixel width in millimeters, we can calculate what the theoretical coin radii would be in pixels.

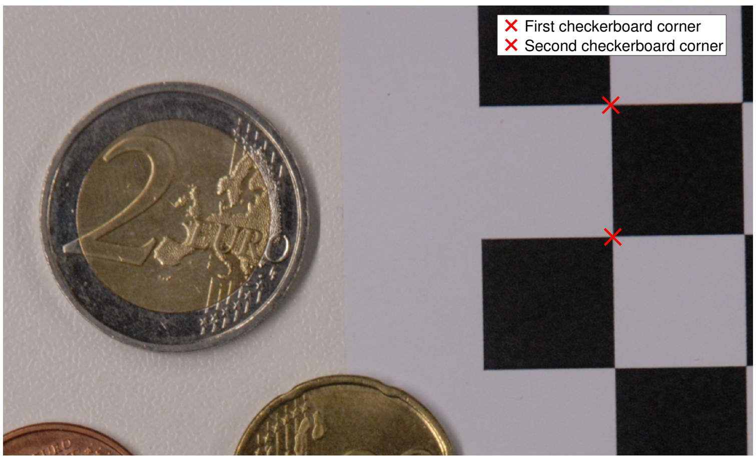

Figure 1. Finding the checkerboard corners for geometric mapping.

Resizing and transforming the images might be needed in the cases of measured images having distortion. However since the test images used are taken from the same angle, on a flat surface with same camera parameters, there is no need to resize or apply any transformation to the images.

2.2 Algorithm for finding the coins in the image

Finding the coins from the measured image is done by using the algorithm 1. Example images of the algorithm steps are presented on the figures 2a – 2h.

Algorithm 1 Coin detection from image

Input: RGB image I(x,y,z), mean bias image MB(x,y), mean dark image MD(x,y), mean flat image MF(x,y).

Output: Six-element vector with number of coins from 5ct to 2e.

1. Calibrate the intensity of image I(x,y,z) using the images MB(x,y), BD(x,y) MF(x,y) and formula (1) to produce calibrated image RI(x,y,z).
2. Apply gray scaling to the calibrated image RI(x,y,z) to produce gray scaled image GI(x,y).
3. Apply edge detection to GI(x,y) to produce binary image BW(x,y) of the edges.
4. Apply binary dilation [2] to the image BW(x,y) using disk shaped morphological structuring element SE(x,y) with suitable radius to produce dilated binary image DBW(x,y).
5. Fill the empty spaces in the image DBW(x,y) to produce filled binary image FBW(x,y) [3].
6. Apply binary erosion [2] to the image FBW(x,y) using the SE(x,y) to produce eroded binary image EBW(x,y).
7. Find the circles in the image EBW(x,y) using Circular Hough Transform (CHT) algorithm [4].
8. Calculate the radii of found circles and classify the coins in the image based on the theoretical radii of Euro coins.

2.2.1 Intensity calibration

For the intensity calibration process, there is gathered five bias, dark and flat images of the imaging setup. The images are combined together in a mean bias (MB), dark (MD) and flat (MF) images. During the calibration, firstly the MB image is reduced from the MD

image. After that, the MB and the new MD image is reduced from the MF image. Then the MF image is normalised so its mean value will be 1. After that the new intensity calibrated image can be created with the following formula

$$R_c = \frac{R - MB - MD}{MF}, \tag{1}$$

where R_c is the calibrated image, R is the measured raw image, MB is the mean bias image, MD is the modified mean dark image and MF is the modified mean flat image. Example of original raw image R can be seen on the figure 2a, and the intensity calibrated image R_c can be seen on the figure 2b.

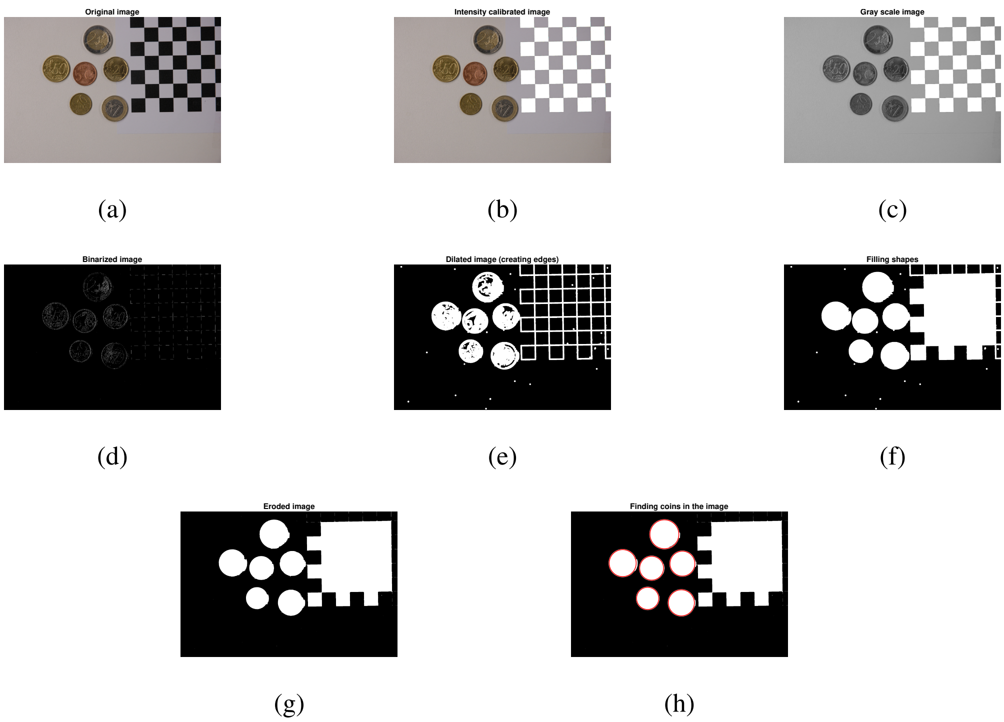

Figure 2. Image processing steps: (a) Original image. (b) Intensity calibration. (c) Transforming image into grayscale. (d) Binarizing the image. (e) Performing dilation. (f) Filling the shapes. (g) Eroding the image. (h) Finding circles in the image.

3 RESULTS & CONCLUSION

The image measurement setup is tested with twelve different images, each image containing different numbers of different coin types in different locations (when compared to the checkerboard). When the radius of the neighborhood for morphological structuring element is estimated to be 15 and the sensitivity for recognizing circles in the image is estimated to be 0.97, every coin for every test image is managed to detect correctly.

Even though the measurement accuracy for this implementation is reached to be as high as 100%, there's still left some uncertainty. Both the radius of neighborhood and the sensitivity are somewhat high values. When radius for dilation and eroding is too wide, the chances for incorrect detections increases, especially when coins are located either close to each others or above the checkerboard. Moreover, the closer the sensitivity is to 1, the shapes are detected more sensitively, and the detection can happen even where they don't exist. Twelve test images is rather small number of training material, so to decrease the uncertainty in coin detection, more images could be gathered and see how well the measurement system performs on them. Based on these results, the measurement system can be modified to be more reliable and the actual measurement accuracy can lower a bit.

All in all, the image measurement setup to detect coins in the image designed in this assignment seems to work very well at least with the given test image set, but in general the detection accuracy will probably vary a lot depending on the images. So for more general solution, further investigation is needed.

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