DETERMINING THE SIZE OF A SKIN LESION USING SMARTPHONES

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ABSTRACT

The objective of this project is to determine the area of a skin lesion from a photo and calculate the lesion diameter to help automatically diagnose melanoma. The American Cancer Society recognizes the guidelines of asymmetry, border irregularity, color irregularity *and* diameter *as markers for possible melanomas; lesions with a diameter greater than 6 mm may need to be examined by a doctor. Because of variable distances between the phone camera and the lesion in question, the size of the lesion changes in comparison to the picture. Two methods have been developed for determining the area of a lesion within a close proximity to the camera. The reference-based method uses a coin of known size as a reference and utilizes the automatic image segmentation and recognition capabilities of OpenCV on Android to calculate the area of a lesion. The focus-distance-based method uses the focus distance returned by the phone camera to determine the distance from the camera to the lesion. Then from the size of the lesion image and the corresponding distance, the actual size of a lesion can be calculated. The two methods were tested through experiments with various objects at different distances from 10 to 15 cm. Experimental results show that the reference-based method produces diameter estimations with errors typically less than 3% and an average error of 0.96%. The errors of the focus-distance-based method are less than 13% with an average error of less than 5%. Though more accurate, the reference-based method requires the user to have a coin with them when they use the app. Both methods are successful and are being incorporated into our automatic melanoma detection app on Android smartphones.*

1 INTRODUCTION

According to the American Cancer Society, melanoma accounts for the most skin cancer related deaths but less than 5% of the total number of skin cancer cases. The estimation of the number of new melanoma cases in 2011 is 70,230. Early detection is very important because the disease is most curable in its beginning stages. This project is an extension of a melanoma detection application, which uses pictures on a smartphone to locally detect the possibility of malignant skin lesions. This app is useful because it will encourage more people to have their lesions inspected by a health professional. Prior to the start of this project, the development of methods to determine the size of a lesion from a photo, the main application evaluated lesions for color regularity and border regularity. Those attributes are 2 of the 5 recognized as the ABCs of melanoma: *asymmetry, border regularity, color regularity, diameter*—lesions with diameters larger than 6mm are at risk, and *evolution*[1].

To carry out the objective of this project, methods needed to be developed to determine the size of a lesion from a picture. This question is non-trivial because of the variable distances from an object at which a picture may be taken. The distance between the camera and the lesion in question means alters the relationship between pixels and actual size making pixels an inaccurate metric.

The following paper will be an explanation of the methodology used in development and an evaluation of the developed methods following extensive testing.

2 Methodology

Two methods were designed to determine the distance between the lesion and the smartphone camera. This section describes the details of the devised methods.

2.1 Focus-distance

The focus-distance-based method uses the getFocusDistances() method provided by the Android API starting at Level 9[2] as well as image processing capabilities of the **Open** Source **C**omputer **V**ision (OpenCV) Library[3]. The getFocusDistances() method returns three measurements for the image's depth of field. The depths of field measurements are meter values for the distances in which objects appear in near, optimal, and far focus. To test the readings from the method several pictures were taken of nickel and quarter coins at every centimeter interval from 10 cm to 15 cm. The initial readings from the getFocusDistances() method had error rates ranging from 4.00% to 353.33% with a mean of 123.32% and a standard deviation of 85.39%[1].

Using the mean returned values for near, optimal, and far focal distances, three functions were found to normalize the values[2]. The normalizing functions can be found below.

```
//**************************************************************
// toReal:: normalizes the values returned by getFocusDistances()
// after they have been converted to centimeters. Input and output
// should be 3 index float arrays and the unit of measure should be
// centimeters.
//**************************************************************
public float[] toReal(float[] returnedCentimeters)
{
   float real[] = new float[3];
   //near
   real[0] =(float)((returnedCentimeters[0]+41.92)/5.3);
   //optimal
   real[1] = (float) ((returnedCentimeters[1]+57.51)/6.8714);
   //far
   real[2] = (float) ((returnedCentimeters[2]+85.591)/9.6131);
return real;
}
```

Once the normalized distances are found, the pixel area found from OpenCV must be converted into square millimeters. Using the pictures taken during the tests for getFocusDistances() accuracy, the number of pixels per square millimeters was found for each coin in every picture. The average number of pixels per square millimeter was found and used to determine a function for estimating the conversion between pixels and millimeters at any given distance. The relationship between pixel area and square millimeters can be defined by the function $f(x) = 13.885x^2 - 455.42x + 4079.1$ where x is the distance between the object and the camera.

To use this function, the average of all 3 normalized values is substituted for x in order to determine the number of pixels per square millimeters in each picture. When that value is found, the area of the object in square millimeters can be found by dividing the object's pixel area by the number of pixels per square millimeter.

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[1] See Figure 1

[2] See Figure 2

Finding the area of the quarter, 462.24 mm^2, using the focus-distance method returned measurements with a mean of 462.02 mm^2, a standard deviation of 47.74 mm^2, and a maximum error of 24.53%[3]. When estimating the area of the nickel, 353.32 mm^2, the focus-distance method yielded a mean of 353.47 mm^2, a standard deviation of 37.24 mm^2, and a maximum error of 26.30%[4].

Since lesions with an area of 28.27 mm^2 are at risk for melanoma, the standard deviations of the focus-distance-based tests were cause for concern. However, it was found that by using the estimated areas to calculate the diameter, $D = 2 * \sqrt{\frac{A}{\pi}}$, the error rate could be made approximately 2 times smaller. This reduction of error could be account for by the relationship between the differentials of area and diameter.

Let A be area and D be diameter and let the percent errors of area and diameter be represented by $\frac{\Delta A}{A}$ and $\frac{\Delta D}{D}$, respectively.

$$Note: A = \frac{\pi D^2}{4}$$

Then,

$$\Delta A = \frac{\pi D \Delta D}{2} \Rightarrow \frac{\Delta A}{A} = \frac{\frac{\pi D \Delta D}{2}}{A} \Rightarrow \frac{\Delta A}{A} = \frac{\frac{\pi D \Delta D}{2}}{\frac{\pi D^2}{4}}$$

$$\Rightarrow \frac{\Delta A}{A} = 2\frac{\Delta D}{D}$$

Using the estimated area of the quarter to calculate its diameter, 24.26 mm, there was a mean diameter measurement of 24.22 mm, a standard deviation of 1.24 mm, and a maximum error of 11.59%[5]. Calculating the diameter of the nickel, 21.21 mm, by using its estimated area yielded a mean of 21.19 mm, a standard deviation of 1.10 mm, and a maximum error of 12.38%[6].

2.2 Reference-based

The reference-based method uses the image processing capabilities of the OpenCV Library to determine compare the area of an object of known size with that of a lesion of unknown size.

The user takes a picture including both the lesion in question and a coin of known size. Using the method *cvFindContours()* to detect the pixels on the outer borders of both the reference object and the lesion. The method *cvContourArea()* is then used to determine the area in pixels of each contour[3].

The number of pixels per square millimeter is found by dividing the pixel area of the coin by its area in square millimeters. The number of pixels per square millimeter in the image to find the lesion area in square millimeters then divides the pixel area of the lesion.

To verify the accuracy of this method, several pictures were taken of a nickel and quarter at every centimeter from 10 to 15 cm. Using the nickel as a reference object to estimate the area of a quarter, 462.24 mm^2, resulted in measurements with a mean of 461.99 mm^2, a standard deviation of 8.83 mm^2, and a maximum error of 4.34%[7]. Estimating the area of a nickel, 353.32 mm^2, using the quarter as a reference object yielded a mean of 353.64 mm^2, a standard deviation of 6.67 mm^2, and a maximum error of 4.16%[8].

In order to compare the two methods, results from the methods needed be of the same type. Therefore, the areas found by the reference-based-method were used to calculate diameter for each of the coins. Using the estimated areas of the quarter to determine its diameter, 24.26 mm, yielded a mean diameter of 24.25 mm, a standard deviation of .23 mm, and a maximum error

[3] See Figures 3 and 4
[4] See Figures 5 and 6
[5] See Figures 7 and 8
[6] See Figures 9 and 10
[7] See Figures 11 and 12
[8] See Figures 13 and 14

of 2.15%[9]. Determining the diameter of the nickel, 21.21 mm, using its estimated areas returned a mean of 21.22 mm, a standard deviation of .20 mm and a maximum error of 2.10%[10].

3 Conclusions

The error percentages indicate that the reference-based method typically provides more accurate measurements than the focus-distance-based method. Despite the higher error rate, the focus-distance-based method is more convenient for users because it does not require any additional items. The focus-distance-based method can only be used at relatively close proximity because the auto-focus on the phone camera looses precision as distance increases. Also, the focus-distance-based method can only be used when a picture is taken in-app because the Android Camera Application doesn't store the depth of field measurements.

The reference-based method provides highly accurate readings but requires the user to have a reference object when they take a picture. The reference-based method provides accuracy at distances farther than the focus-distance based method. The reference-based method does have the advantage of allowing the picture to be taken outside of the app and then imported in.

Testing confirms that both methods can successfully estimate the diameter of a lesion. Both methods are being implemented into the ongoing development of a Melanoma Detection Application.

4 Future Work

As a part of the ongoing development of an application to automatically and locally diagnose melanoma using smartphone cameras, additional methods will be developed for detecting the amount of asymmetry in a lesion. Also, a way to track changes to a lesion will be developed in order to determine the lesions evolution. Combined with methods already implemented in the detection application and the methods described in this paper, the asymmetry and evolution determining methods will aide in the early detection of melanoma.

[9] See Figures 15 and 16

[10] See Figures 17 and 18

References

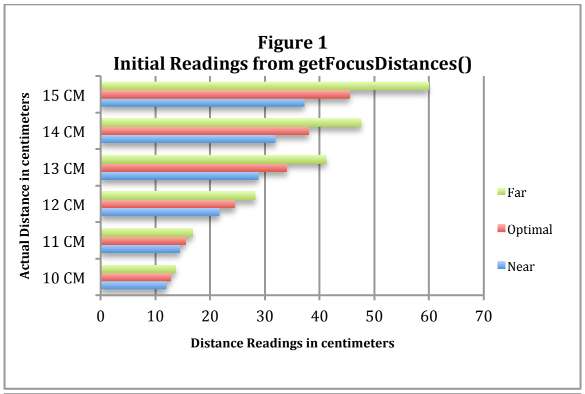
[1] American Cancer Society. "Melanoma Skin Cancer Overview." *Cancer.org*. American Cancer Society, 21 June 2011. Web. 27 July 2011. <http://www.cancer.org/acs/groups/cid/documents/webcontent/003063-pdf.pdf>.

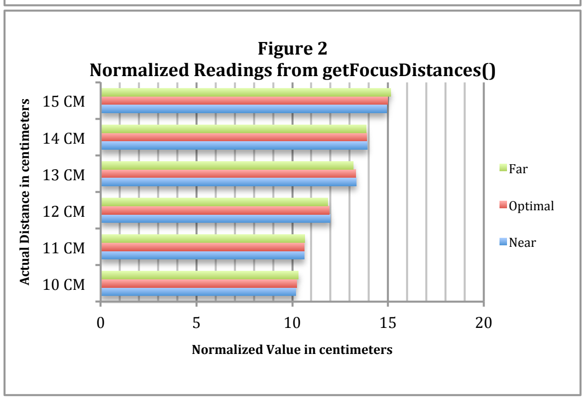
[2] *Android Developers*. Web. 27 July 2011. <http://developer.android.com>.

[3] OpenCV Development Team. *OpenCV v2.3 documentation.* opencv dev team, 07 Jul 2011. *Web. 27 Jul 2011. <http://opencv.itseez.com/>.*

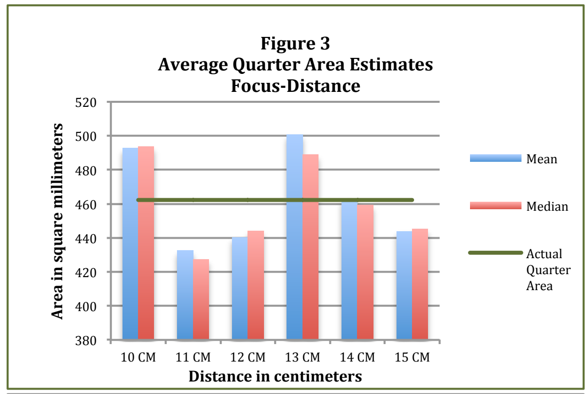
Figures

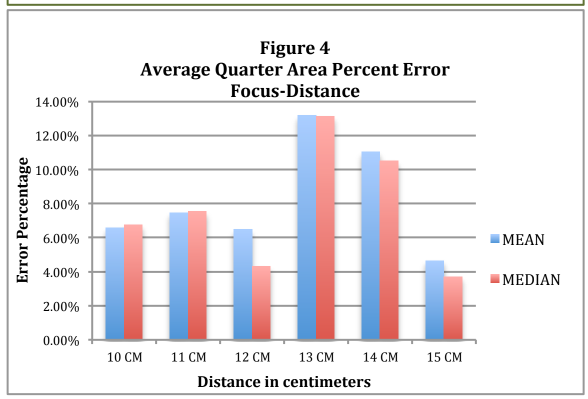
Distance Readings

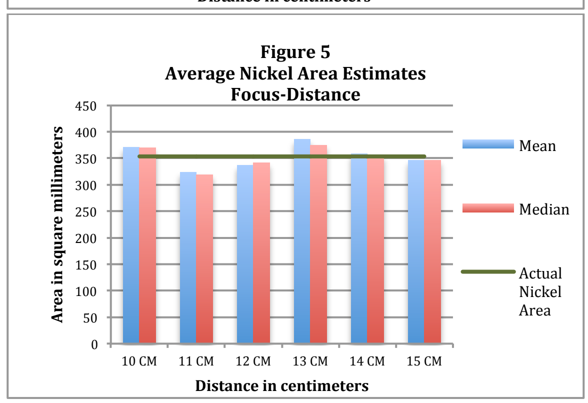


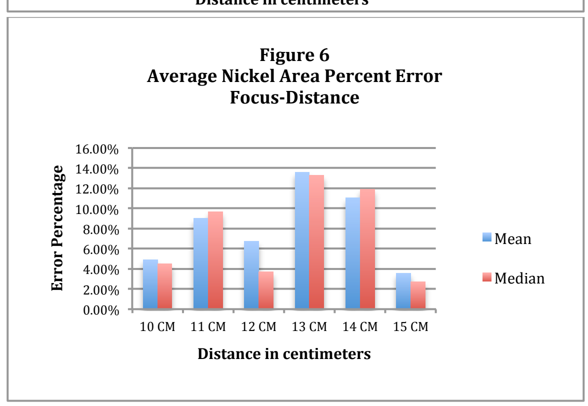


Focus-Distance Area

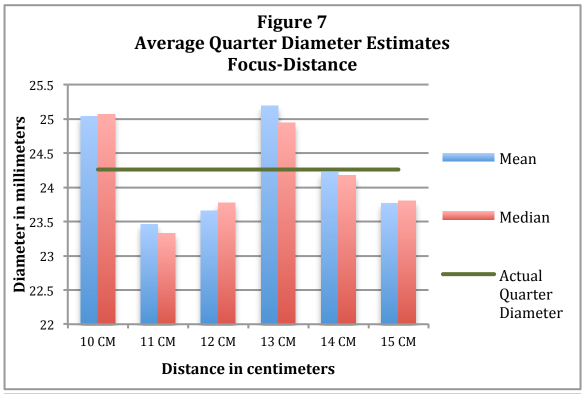


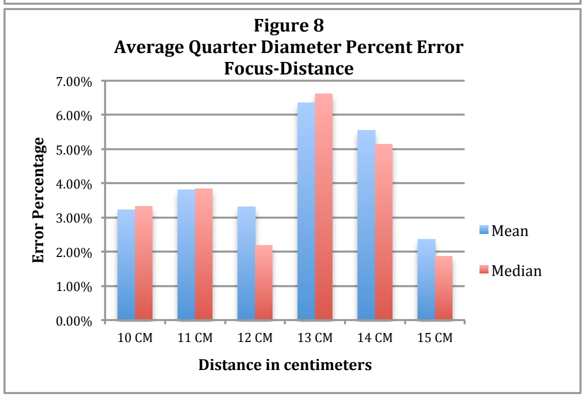


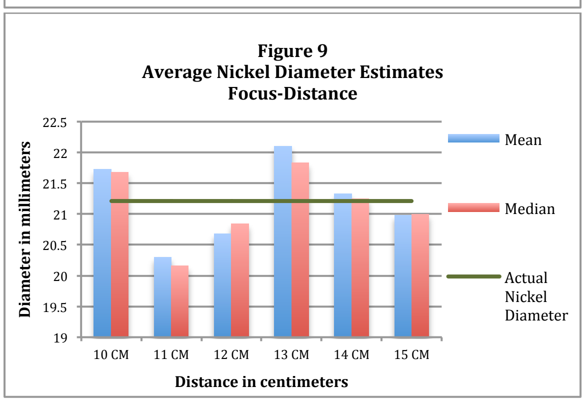


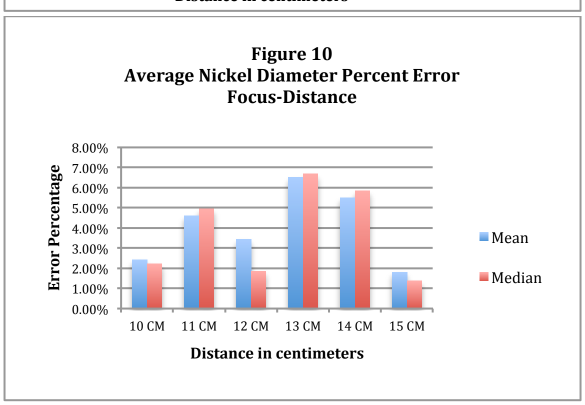


Focus-Distance Diameter

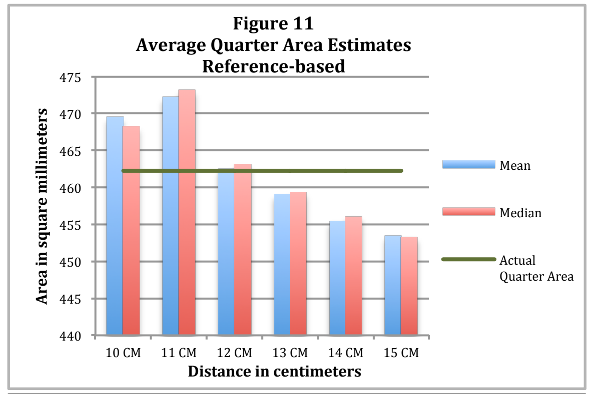


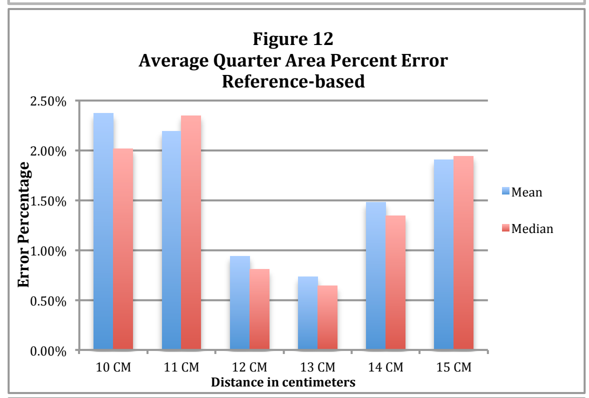


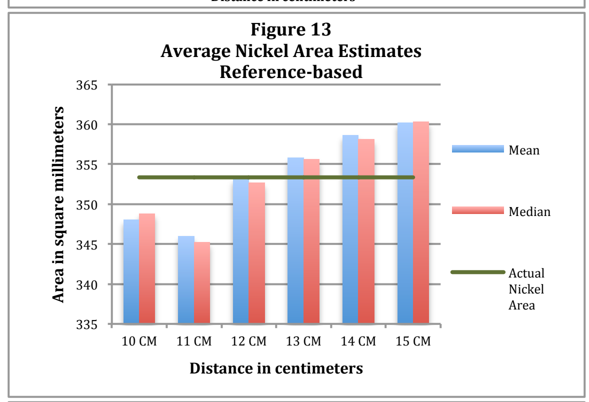


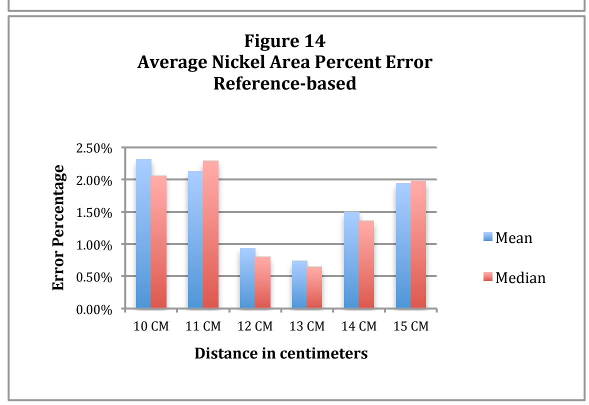


Reference-based Area









Reference-based Diameter

Figure 15
Average Quarter Diameter Estimations
Reference-based

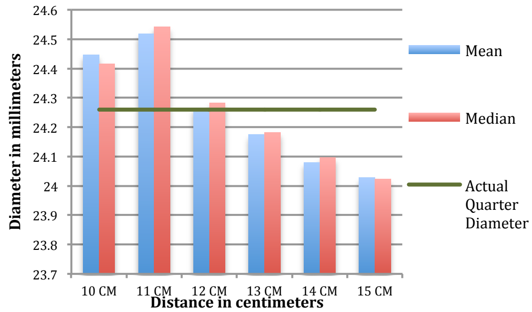


Figure 16
Average Quarter Diameter Percent Error
Reference-based

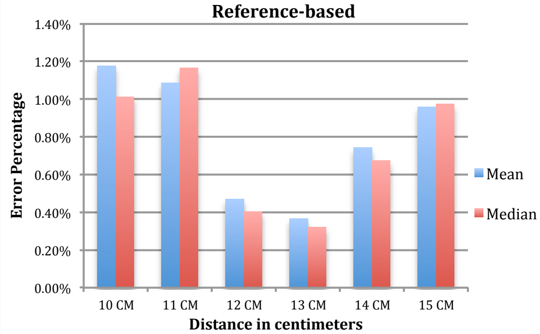


Figure 17
Average Nickel Diameter Estimations
Reference-based

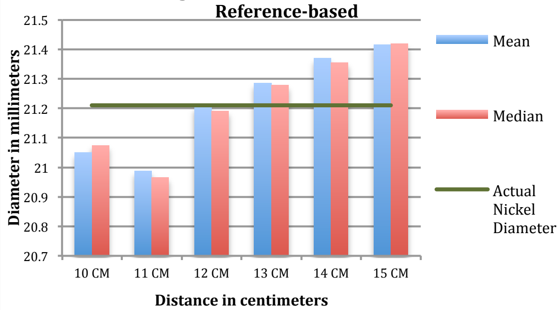


Figure 18
Average Nickel Diameter Percent Error
Reference-based