Mobile Detection Glaucoma System using Deep Learning

Sarvesh Wani[1], Krishna Mohan Singh[2], Yash Pancholi[3], Bhavya Shah[4]

[1-4]Sandhaya Kadam, Dept. of EXTC Engineering, K.JSIEIT Mumbai college, Maharashtra, India

---***---

Abstract— Glaucoma is a debilitating optical degeneration disease that can lead to vision loss and eventually blindness. Given its asymptomatic nature, most people with Glaucoma aren't even aware that they have the disease. As a result, the disease is often left untreated until it is too late. Detecting the presence of Glaucoma is one of the most important steps in treating Glaucoma, but is unfortunately also the most difficult to enforce.

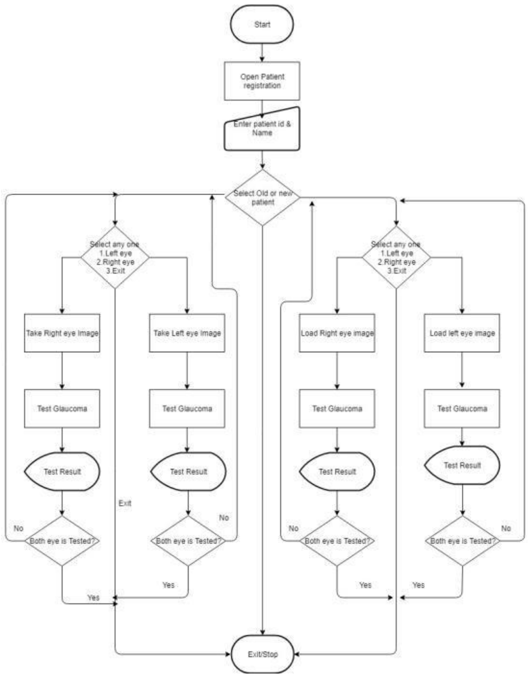
The Mobile Glaucoma Detection application aims to reduce the growing number of individuals who are unaware that they have Glaucoma by providing a simple detection mechanism to notify users if they are at risk. The system does this by enabling its users to independently conduct Tonometry exams through the application. Tonometry examinations allow doctors to determine if the intra-ocular pressure levels in a person's eyes put them at risk for Glaucoma. The M.G.D.A(Mobile Glaucoma Detection Application) allows users to determine their intra-ocular pressure levels from the comfort of their own home with a smartphone application. The system also offers users the opportunity to monitor, regulate, and track their use and progress through the system.

INTRODUCTION

Glaucoma is a disease that damages the optic nerves in an eye, plagues hundreds of millions of people throughout the world. This normally benign condition, can exacerbate into a much more serious conditions such as blindness and infections due to lack of treatment. Glaucoma is asymptomatic and is thus difficult to detect. As a result, the rate at which Glaucoma goes undetected and untreated is exceptionally high. This leads to millions of people throughout the world losing their vision and quality of life to an otherwise preventable cause. Glaucoma is an easily treatable condition as long as it is detected early on into its development. If left to spread and worsen, the disease will begin to damage the person's optical nerves and degenerate their ability to see.

Current methods of detecting Glaucoma is a highly involved and complicated process. The most common method of detecting Glaucoma is conducting a Tonometry test which takes advantage of the fact that the most common form of Glaucoma generally causes a significant increase in eye pressure which can be detected and used to gauge the probability that the patient has the disease. The test requires both involvement from the doctor, a specialized and expensive pressure sensitivity machine, and the availability of a properly trained operator. The machine that conducts the Tonometry test is both expensive and bulky meaning that it is inoperable in areas that cannot support the infrastructure necessary to utilize it. What's worse is the fact that in many poorer parts of the world, the machine is simply too expensive to purchase and use on a population that is deemed either too small or financially unviable to justify the purchase. Thus large portions of the population simply go untreated because it doesn't economically make sense to provide the service. On top of that, current methods of detecting Glaucoma require consistent regular visits in order to gauge whether Glaucoma has formed or if it has gotten worse. All of these factors make it extremely difficult for people to get the check ups they need to prevent the disease from forming.

Our goal is to create a mobile smartphone application that provides a robust and flexible way of conducting Tonometry tests. We intend to create an application that utilizes the camera feature of the smartphone to interface with a simple implantable optical sensor in order to detect the different levels of pressure in the eye. This setup would replace the expensive Tonometry machines used by optometrists to detect. The smartphone application would allow patients to have quick, convenient, and affordable access to one of the most useful Glaucoma detecting tests. This would increase the percentage of people able to get tested and hopefully allow more patients to detect the disease early if it is present. The application would also provide a significant benefit to patients that already have Glaucoma, giving them the ability to regularly monitor the status of their condition. Through this application, millions of people would be empowered with the ability to easily and affordably check for the most common signs of Glaucoma, hopefully providing an opportunity to respond early and combat the disease. The problem of glaucoma detection can be broken down into the following functional and nonfunctional requirements. Functional requirements define what the Glaucoma detection application must achieve. Non-Functional requirements define how the functional requirements will be achieved. Lastly, design constraints define the restrictions placed on the design itself.

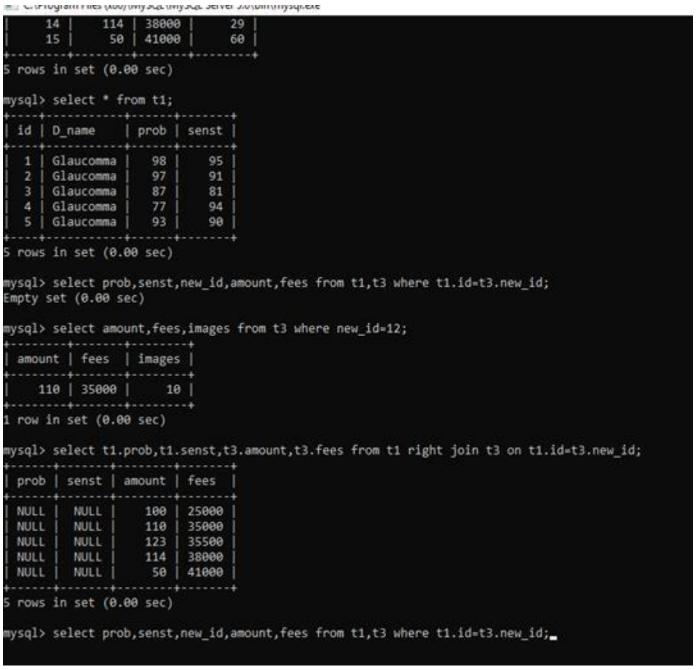


Application Software Flowchart

GLAUCOMA DETECTION USING PYTHON

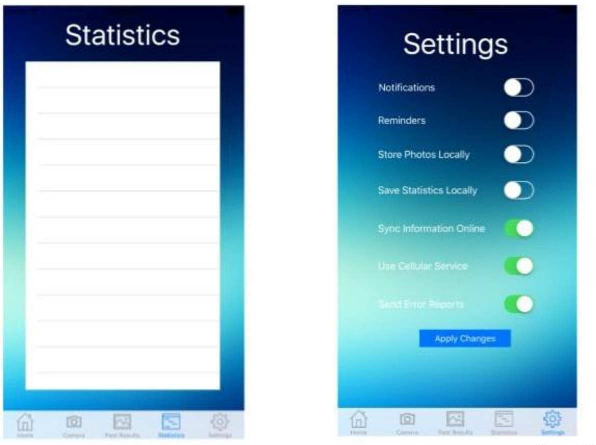
An accurate Glaucoma detection is among one of the crucial requirements to control its progression and reduce the risk of blindness. In biomedical imaging glaucoma detection is one of the active researches being done in the field of autonomous glaucoma detection systems to provide state of art computer aided design (CAD) tool that can aid ophthalmologists in early glaucoma detection. Many image processing, computer vision and machine learning techniques and tools are being used to excel in this research field and come up with more accurate results that might help in more accurate and early glaucoma diagnosis. Some state of art methodologies are being discussed in the upcoming section.

An Optic disc localization algorithm (GeethaRamani and Dhanapackiam 2014) implemented template matching technique to locate optic disc center. Template was created by averaging the images in the database. Green plane was processed further using some morphological operations to detect the Optic disc. In 2014, a disc localization algorithm (Akhade et al. 2014) performed principal component analysis (PCA). Most significant principal component was further processed to remove vessels using morphological operations. Circular Hough transformation was applied to detect the circular body from the resultant fundus image. Tan et al. (2010) used Gaussian Mixture Models (GMM) to extract cup region from fundus images. Resulting cup region has good boundary results in temporal region, while cup extraction algorithm in ARGALI performs well in nasal region, thus a hybrid cup extraction was done by fusion of both ARGALI detected boundary and proposed algorithm detected boundary. Algorithm was tested on 71 images and 14 % error reduction was observed. Cup detection algorithm based on vessel kinking was proposed in Damon et al. (2012). Algorithm proceeds with detecting vessels by classifying some patches of interest by using features like mean and standard deviation of a fused image formed after computing wavelets of edges of green red component and gradient of green component. Vessel kink detection was completed by localizing maximum curvature of the detected vessels. Algorithm evaluation was done on 67 images, and has reduced 43.3 % errors in cup boundary detection. A spatial heuristics based analysis was done to extract cup (Wong et al. 2012) after fusing two segmentation techniques i.e. Level set technique applied on green channel to extract brightest pixels from the image and Color histogram approach which selects pixels in a certain range in red, green and blue plane by region growing. Cup boundary was extracted by fusing the two segmentation techniques for the reason that both techniques perform differently in the inferior, superior, nasal and temporal regions. Best key point at each phase shift was determined using Bayesian score to select the boundary of cup from the two segmentation techniques. Local patching i.e. Super pixel segmentation and grid decomposition techniques (Xu et al. 2014) were applied to segment cup from the rest of the fundus image.



```
|     14 |     114 | 38000 |      29 |
|     15 |      50 | 41000 |      60 |
+--------+---------+-------+---------+
5 rows in set (0.00 sec)

mysql> select * from t1;
+----+-----------+------+-------+
| id | D_name    | prob | senst |
+----+-----------+------+-------+
|  1 | Glaucomma |   98 |    95 |
|  2 | Glaucomma |   97 |    91 |
|  3 | Glaucomma |   87 |    81 |
|  4 | Glaucomma |   77 |    94 |
|  5 | Glaucomma |   93 |    90 |
+----+-----------+------+-------+
5 rows in set (0.00 sec)

mysql> select prob,senst,new_id,amount,fees from t1,t3 where t1.id=t3.new_id;
Empty set (0.00 sec)

mysql> select amount,fees,images from t3 where new_id=12;
+--------+-------+--------+
| amount | fees  | images |
+--------+-------+--------+
|    110 | 35000 |     10 |
+--------+-------+--------+
1 row in set (0.00 sec)

mysql> select t1.prob,t1.senst,t3.amount,t3.fees from t1 right join t3 on t1.id=t3.new_id;
+------+-------+--------+-------+
| prob | senst | amount | fees  |
+------+-------+--------+-------+
| NULL |  NULL |    100 | 25000 |
| NULL |  NULL |    110 | 35000 |
| NULL |  NULL |    123 | 35500 |
| NULL |  NULL |    114 | 38000 |
| NULL |  NULL |     50 | 41000 |
+------+-------+--------+-------+
5 rows in set (0.00 sec)

mysql> select prob,senst,new_id,amount,fees from t1,t3 where t1.id=t3.new_id;
```

Database



Application Preview

In the title or heads unless they are unavoidable.

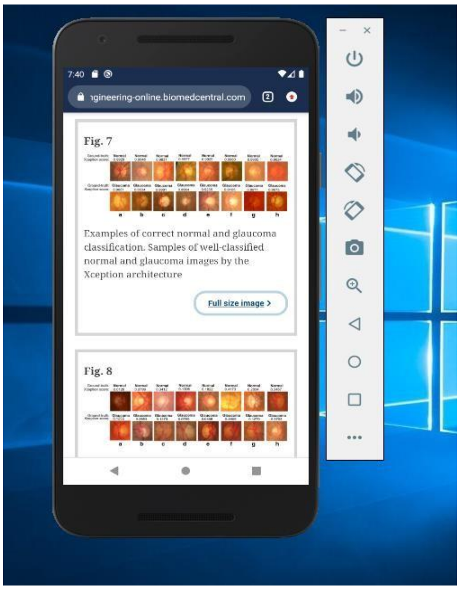
IV. Non-Functional Requirements

The application will function on all major iOS devices: iPhone 6, iPhone 6 Plus, iPhone 6S, iPhone 6S Plus.

The website will be compatible with all major web browsers: Chrome, Firefox, Safari, and Internet Edge.

The application will be user friendly.

The application will be easily manageable by the user. The information maintained on the system by date.



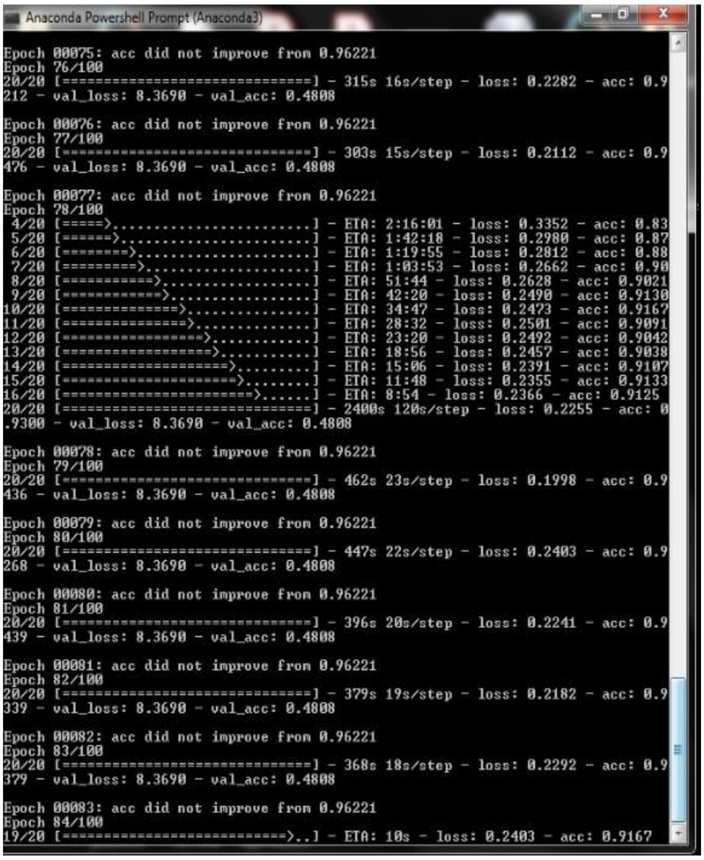
Design Rationale Technology:

Our system utilizes both a website as well as an iOS application. The website is compatible with all major web browsers and details information relevant to the application. The website utilizes HTML/CSS for the front end and for any visuals on the site. The website is responsive and compatible with multiple different screen sizes including tablet and smartphone. The website takes advantage of the latest version of wordpress as well to enable future modification from individuals unfamiliar with the code structure. Additionally it will allow future developers to add modules to the site independent from the modifications we already made.

Our team are utilizing HTML/CSS to create the webpage for variety of reasons. HTML/CSS is the preeminent language combination used to create modern day webpages. It is widely regarded as the standard when it comes to website development and is fullycompatible with all major web browsers on all major device platforms. This includes iOS, Android, Windows, Mac, and Linux. Additionally all our team members have extensive experience with HTML/CSS so very little time will be needed to attain an equal level of skills on that front. Javascript was chosen for similar reasons. Javascript goes hand in hand with HTML/CSS and all team members involved have a decent degree of experience with it. Javascript is also compatible with all major systems the application will be built for and interfaces very well with HTML/CSS. Additionally Javascript will allow us to create custom form animations and utilize many other libraries that will expedite the development process. PHP was chosen for backend functionality due to its compatibility with all major web hosting providers and its ability to interface well with HTML/CSS/Javascript. PHP also allows for easy form creation and has a host of useful libraries and frameworks that could be useful for future development.The Swift programming language was chosen due to its widespread support byApple.

UI/UX:

We expect that the users interactions with our system to revolve around two primary actions: Taking pressure level measurements(Figure 4) and viewingpast results(Figure 5). As a result, our iOS design will focus on channeling the user towards those two main actions. The buttons for those actions will be centrally located on the bottom center ofthe navigation bar and have text that are slightly more pronounced than the rest of the features on the navigation bar. The user flow for those features will also be more streamlined so that the user won't have to struggle to use those primary features.



```
Anaconda Powershell Prompt (Anaconda3)
Epoch 00075: acc did not improve from 0.96221
Epoch 76/100
20/20 [==============================] - 315s 16s/step - loss: 0.2282 - acc: 0.9
212 - val_loss: 8.3690 - val_acc: 0.4808

Epoch 00076: acc did not improve from 0.96221
Epoch 77/100
20/20 [==============================] - 303s 15s/step - loss: 0.2112 - acc: 0.9
476 - val_loss: 8.3690 - val_acc: 0.4808

Epoch 00077: acc did not improve from 0.96221
Epoch 78/100
 4/20 [=====>........................] - ETA: 2:16:01 - loss: 0.3352 - acc: 0.83
 5/20 [======>.......................] - ETA: 1:42:18 - loss: 0.2980 - acc: 0.87
 6/20 [========>.....................] - ETA: 1:19:55 - loss: 0.2812 - acc: 0.88
 7/20 [=========>....................] - ETA: 1:03:53 - loss: 0.2662 - acc: 0.90
 8/20 [===========>..................] - ETA: 51:44 - loss: 0.2628 - acc: 0.9021
 9/20 [============>.................] - ETA: 42:20 - loss: 0.2490 - acc: 0.9130
10/20 [==============>...............] - ETA: 34:47 - loss: 0.2473 - acc: 0.9167
11/20 [===============>..............] - ETA: 28:32 - loss: 0.2501 - acc: 0.9091
12/20 [=================>............] - ETA: 23:20 - loss: 0.2492 - acc: 0.9042
13/20 [==================>...........] - ETA: 18:56 - loss: 0.2457 - acc: 0.9038
14/20 [====================>.........] - ETA: 15:06 - loss: 0.2391 - acc: 0.9107
15/20 [=====================>........] - ETA: 11:48 - loss: 0.2355 - acc: 0.9133
16/20 [=======================>......] - ETA: 8:54 - loss: 0.2366 - acc: 0.9125
20/20 [==============================] - 2400s 120s/step - loss: 0.2255 - acc: 0
.9300 - val_loss: 8.3690 - val_acc: 0.4808

Epoch 00078: acc did not improve from 0.96221
Epoch 79/100
20/20 [==============================] - 462s 23s/step - loss: 0.1998 - acc: 0.9
436 - val_loss: 8.3690 - val_acc: 0.4808

Epoch 00079: acc did not improve from 0.96221
Epoch 80/100
20/20 [==============================] - 447s 22s/step - loss: 0.2403 - acc: 0.9
268 - val_loss: 8.3690 - val_acc: 0.4808

Epoch 00080: acc did not improve from 0.96221
Epoch 81/100
20/20 [==============================] - 396s 20s/step - loss: 0.2241 - acc: 0.9
439 - val_loss: 8.3690 - val_acc: 0.4808

Epoch 00081: acc did not improve from 0.96221
Epoch 82/100
20/20 [==============================] - 379s 19s/step - loss: 0.2182 - acc: 0.9
339 - val_loss: 8.3690 - val_acc: 0.4808

Epoch 00082: acc did not improve from 0.96221
Epoch 83/100
20/20 [==============================] - 368s 18s/step - loss: 0.2292 - acc: 0.9
379 - val_loss: 8.3690 - val_acc: 0.4808

Epoch 00083: acc did not improve from 0.96221
Epoch 84/100
19/20 [===========================>..] - ETA: 10s - loss: 0.2403 - acc: 0.9167
```

Output of Convolution Neural Network Epoch

The interface will be intuitive throughout the application and will follow a theme the user is already familiar with from other iOS applications. Certain elements of the application will be strategically located so that the user naturally gravitates towards that direction of the screen. An example of this would be how most iOS applications have the navigation bar located towards the bottom of the screen. Our application interface will mimic those design choices so that the user doesn't have to relearn how to use the application.

The website will follow similar queues taken from the iOS application. More commonly used aspects of the system will be located in areas the user's mouse subconsciously gravitates towards. The buttons will be larger so that they are easier to click on and have text that are easier to read. An example can be seen in figure 6 when the user attempts to "analyze" an image. The overall layout will follow a simple modern design with rounded corners and softer colors. The goal for the website's design is to make it as intuitive of an experience as possible for the users.

Table -1: Sample Table format

Table 1. Measuring Pressure Levels Test Plan

Value	Expected Result	Observed Results
8MP Test Image	Correct IOP Count	Correct IOP Count
Blurred Test Image	Correct IOP Count	Incorrect IOP Count
Out Of Focus Test Image	Correct IOP Count	Incorrect IOP Count
5MP Test Image	Correct IOP Count	Correct IOP Count
3MP Test Image	Correct IOP Count	Incorrect IOP Count

For testing, we wanted to ensure that the system was providing the most accurate results we could possibly deliver. As a result, we attempted to use as many images as possible to properly calibrate our algorithms and filters to match the real world settings the system would likely be used in. Unfortunately, because we were only given a very limited number of test images to work with, we were unable to fully test the system to the degree we had originally intended. We attempted to compensate forthis lack of images by reusing the images we already had but subjecting them to differing conditions regarding light, stability, and focus.

Table 2. Understanding Results Test Plan

Value	Expected Result	Observed Results
Entered IOP Value:30	IOP Warning Message	IOP Warning Message
Entered IOP Value: 15	IOP Normal Message	IOP Normal Message
Entered IOP Value: 8	IOP Low Warning Message	IOP Low Warning Message

Table 5. Risk Analysis

Risks	Severity	Probability	Impact	Consequence	Mitigation
Programming Bugs	8	0.95	7.6	System might not function properly or can possible crash.	Review code submitted to version control. Test as we develop.
Client Wants To Alter Requirements	6	1	6	Changes to system design will have to be made potentially requiring other aspects of the design to be changed.	Ensure clear communicati on with the client so that requirements are clearly established.
Inability To Process An Image	9	0.20	1.8	The application will fail in its main objective: measuring IOP.	Have a variety of images to use a "training images" to test against. Develop quality evaluation method. Manually evaluate by physician if needed.

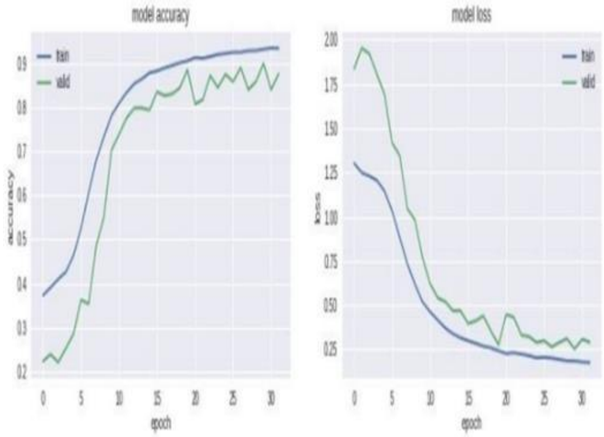
The functionality of our system is derived from three main components . A smart phone application and small contact lens, and a secure magnifying head mount. The smartphone application can easily be downloaded by any iOS device from the app store. Additionally, it can be side loaded to an iOS device by directly connecting to the hosting server. Once the application is on device, it should be good to go as far as that individual component is concerned.

Table 4. Website Test Plan

Value	Expected Results	Observed Results
Website URL entered	Web page loads	Web page loads
Website Screen Size Change	Website elements shift to accommodate smaller screen size.	Website elements shift to accommodate smaller screen size.
Website navigational buttons pressed	Website reveals more information	Website reveals more information.

Results:

1. Probability of Sensitivity of images is: 0.99875.
2. Probability of database connectivity of images is: 0.9875.
3. Probability of fundus images selection is: 0.9905.



Conclusions

Despite some last changes to the requirement conditional data has been used in various medical industries and was able to successfully demonstrate the feasibility of detecting intra-ocular pressure levels through a smartphone application. The application was able to achieve the primary goal of determining a user's IOP curately and quickly in a manner that doesn't require a trained professional Additionally, the system was able to provide a platform for further development that will hopefully see this project move forward into the future. In future there is the opportunity to work on this system and enhance its functionality and feature set with the end goal of being able to launch a full fledged product.

REFERENCES

1. Araci , Ismail E., Baolong Su, Stephen R. Quake, and Yossi Mandel. "An Implantable Microfluidic Device 0.78 web.
2. IEEE code of ethics Web. 01 June 2016.<http://www.ieee.org/about/corporate/governance/ p7-8.html>
3. Image filtering OpenCV 2.4.13.0 Documents http://docs.opencv.org/2.4/modules/imgproc/doc.
4. Features detection canny Documentation opencv on feature_detection.html?highlight=canny#canny.
5. Image filtering and dilate image filering OpenCV2.4.13.0 Documentation.N.p.,n.d Web.
6. Structured analysis and descriptors and shape ananalysis 2.4.13.0 np nd docs.opencv.org.
7. Image filtering and laplacian algorithm open cv nd web 2.4 imgprocs 9 june 2016 docs.opencv.web.
8. Feature detection hough circles 2.4 modules feature detection highlights feature_html hough circle='hog'
9. <http://docs.opencv.org/2.4/modules/imgproc/do c/ structured analysis and phase descriptors html?highlights=contours find approxydn>