AN EARDRUM IMAGE CAPTURE GUIDANCE PROGRAM FOR THE OTOSCOPE

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ABSTRACT

Otitis media (OM) is a disease prevalent among pediatric, and adult population as well. With the advancement of computer vision and Internet of things, it is possible to do a real time analysis for aiding the OM diagnosis by using a digitized otoscope. A professional ENT (Otolaryngology) doctors can use the digitized otoscope to capture a favorable eardrum image for analysis and diagnosis. But not the same on a common home user. Due to lack of the anatomical structure knowledge of middle ear, users may capture an image without the eardrum on it and resulting in bad analysis outcomes. So we want to make a guidance program on the mobile device to aid the home user using an otoscope to capture the favorable eardrum image for diagnosis and continue treatment.

Keywords: *Otitis media, Eardrum, Otoscope.*

1. INTRODUCTION

The concept of telemedicine is applied as the complex integration service in hospital. With the help of FDA approved medical devices, patients or users can be take care by medical service with lower social and financial burden. Especially that OM is the high incidence and recurrence rate disease during the childhood [1].

Due to the advancement of computer vision and internet of things, there are some research for building diagnosis algorithm of OM to aid in doctors [2, 3, 4]. During these researches, the images of eardrum are taken by researcher, nurses, or doctors, who have full knowledge and experience about medicine. When the user changes to general people, most of the digitized otoscope lacks guidance features to help the user in taking available picture for diagnosis. Without a complete and clean eardrum, doctors have difficulty to make a diagnosis and so is the image processing algorithm.

The goal of this study is to make a guidance program for otoscope users. With the help of program, user can take appropriate images for follow up treatment by doctor or supply to the later complicated image analysis. Furthermore, we can collect lots of standard eardrum images to build a database for other use.

2. EARDRUMS AND OTITIS MEDIA

The middle ear is the portion of the ear internal to the eardrum, and external to the oval window of the inner ear [5]. When the otoscope moves in the canal, the eardrum will show on the screen at the end of the canal. The eardrum is a thin, cone-shaped membrane that separates the external ear from the middle ear [6].

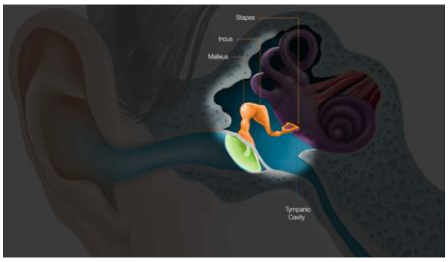

Fig. 1: The middle ear structure.

A circle of thin skin about eight to nine millimeters in diameter, the eardrum is not flat like the skin of a drum, but is slightly conical with the curved sides sloping inwards.

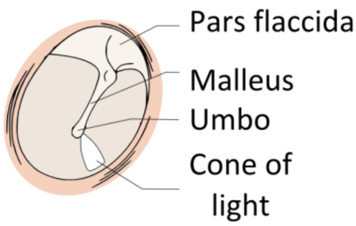

Fig 2: The eardrum structure.

With different type of patients, the ear structure and ear disease are all different. The otitis media (OM) is the most common disease about the eardrum. OM is a group of inflammatory diseases of the middle ear. In young children this may result in pulling at the ear, increased crying, and poor sleep. There are two types of middle ear infections: acute otitis media (AOM) and otitis media with effusion (OME) [7].

The Fig. 3 shows the AOM eardrum images with lots of red area.

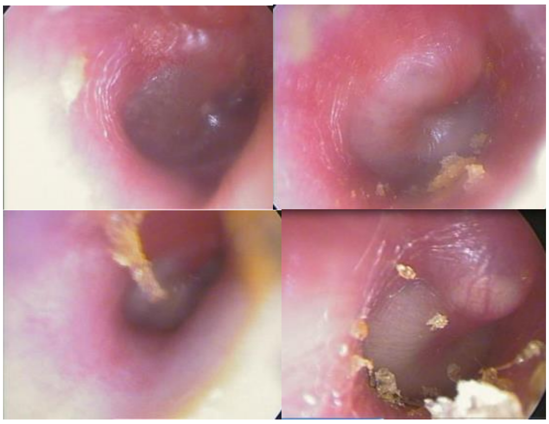

Fig. 3: AOM images.

This type of ear infection comes on quickly and is accompanied by swelling and redness in the ear behind and around the eardrum. Fever, ear pain, and hearing impairment often occur as a result of trapped fluid and/or mucous in the middle ear.

After an infection goes away, sometimes mucous and fluid will continue to build up in the middle ear. This can cause the feeling of the ear being “full” and affect the ability to hear clearly. As the Fig. 4 shows, the OME patients have yellower ear drum or canal on the images.

Fig. 4: OME images.

Except the two type of middle ear infections, chronic suppurative otitis media (COM) is middle ear inflammation of greater than two weeks that results in the hollow or concave on an eardrum.

Fig. 5: COM images.

3. OTOSCOPE

An otoscope is a medical device which is used to look into the ears. Doctors use otoscopes to screen for diseases during regular check-ups and also to investigate ear symptoms. An otoscope potentially gives a view of the ear canal and eardrum.

Because the eardrum is the border separating the external ear from the middle ear, its characteristics can be indicative of various diseases of the middle ear space. The Fig. 6 shows the otoscope included the accessories.

Fig. 6: Otoscope included accessories.

To make a better user experience and operation, a good otoscope may have following features [8]:

(1) Brightness adjustment.
(2) High image resolution.
(3) Photo gallery
(4) Portable SD card
(5) Video out display
(6) Built-in battery for charging.

4. METHOD

The translation between otoscope and mobile device depends on Wi-Fi Internet. In general, the streaming resolution is up to 720P (1280×720 pixels), 30 FPS and save the video in AVI format, image in JPEG. As the otoscope in Fig. 7, user will handhold the otoscope, monitoring on the mobile device and touch the button on the otoscope for capture.

Fig. 7: Otoscope for image capture.

The development environment is Windows 10, Visual Studio 2013, OpenCV 3.3, and Android 4.4. Before deploying to the mobile device, we locally use otoscope without Internet to record video from normal adults and testing these data on pc.

Before the streaming be encoded, each frame can be processed by white balance on the otoscope. After the white balance, the image will be warmer on the screen, which can help doctor to diagnosis the eardrum disease. In this research, we try both of the situations for a better user experience. The Fig. 8 show an eardrum image after the white balance.

Fig. 8: White balance.

With the LED light on camera lens of the otoscope, user can adjust the brightness by touch the button beside the screen. With different brightness, doctors can clearly see the eardrum on the screen.

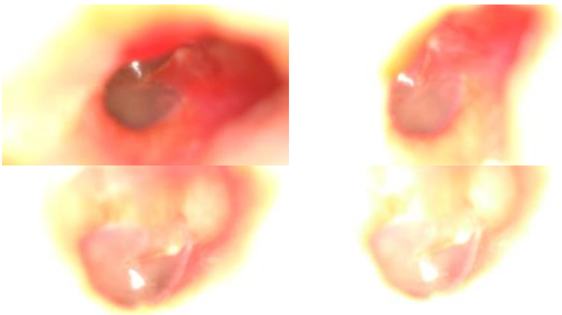

Fig. 9: Different levels of brightness.

To easily clear the otoscope, users can cover a cap on the otoscope to prevent touch the canal when recording the video. As the Fig. 10 shows, there are different types of caps to meet the requirement for the different structures of middle ear.

Fig. 10: Different types of ear cap.

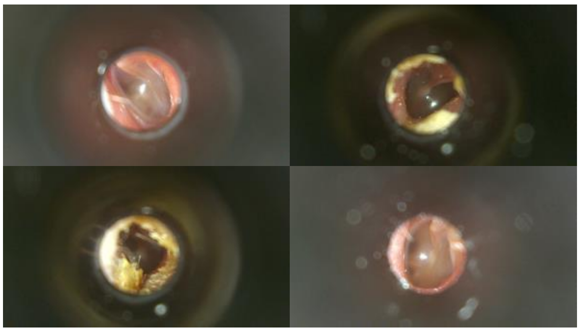

Fig. 11 Image with ear cap.

The video file will be turn into streaming and input to the program. At first, with the OpenCV library, we store each frame by Mat structure and do some preprocessing for analyze. By comparing the channels between each frame in the video, we find that the blue channel has better outcome for finding contours between eardrum and ear canal. For this reason, we will focus on how to mark out the eardrum area and remove the remaining sub-area.

When the algorithm is completed, we will implement it on the mobile OS and process the streaming in real time. Due to the weak computation and resource compare to the computer, this study didn't use the complex method so that the program can run smoothly on the mobile device. With a few steps, we can circle out the foreground by the contours and calculate the area to determine if it is eardrum.

5. STEPS

Fig. 12 shows an original image captured by otoscope. In the center area of image is eardrum with deeper blue and circle shape, where the ear canal area surrounds its red mixed skin.
Because the border between eardrum and ear canal has more different features for drawing contours, we use the following step to mark the eardrum for reminding users to capture the image. With the help of guidance on the screen, user can get an available image with eardrum inside for analyze.

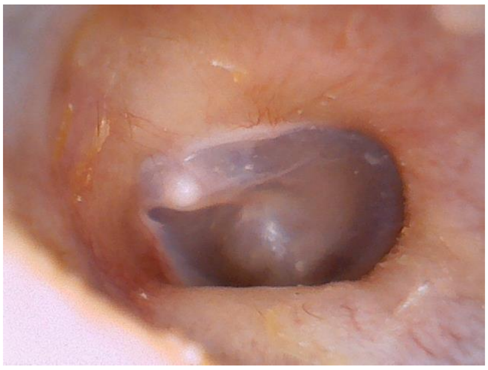

Fig. 12: Original image.

5.1 Pre processing

At the beginning, we load the image by COLOR_IMAGE format which translate the image to BGR 3 channels and store in a Mat structure. With a better recognition result in blue channel, we separate the image to RGB channels and remain blue channel for the next analysis. After the histogram equalization to increase the global contrast, we use Otsu's method to do binarization. As Fig. 13 shows, most of the eardrum area is turn into white and surrounding by black area which is ear canal.

Fig. 13: Binarized image.

5.2 Flood-fill from corners

After binarization, most of the acoustic meatus area on the image are changed to black with the eardrum area is white. To clearly distinguish the eardrum from background, start with four corners, we use the floodFill() function to fill the connected white component with black color.

Flood fill is an algorithm that determines the area connected to a given node in a multi-dimensional array. It always takes three parameters: a start node, a target color, and a replacement color. The algorithm looks for all nodes in the array that are connected to the start node by a path of the target color and changes them to the replacement color. In the Fig 14, the ear canal area is almost filled by black and is ready for finding contours in the image.

Fig. 14: After flood fill from corners.

5.3 Find contours and draw a circle

Closing to enlarge the boundaries of foreground region and find the contours. In this place, we use the findContours() function in OpenCV to find edges of the area. The kernel algorithm of findContours() is the Canny edge detector.

The Canny edge detector was developed by John F. Canny in 1986. It is an edge detection operator that uses a multi-stage algorithm to detect a wide range of edges in images. Canny also produced a computational theory of edge detection explaining why the technique works [9][10].

The processes of Canny edge detection algorithm can be broken down to following steps [11]:

(1) Apply Gaussian filter to smooth the image in order to remove the noise.

(2) Find the intensity gradients of the image

(3) Apply non-maximum suppression to get rid of spurious response to edge detection.

(4) Apply double threshold to determine potential edges.

(5) Track edge by hysteresis: Finalize the detection of edges by suppressing all the other edges that are weak and not connected to strong edges.

After the edge detection, we draw the biggest contours with red line to mark the edge of white area. After all, draw a green minimum circumcircle to cover the contour area which represents the eardrum. With the green circle mark out the eardrum in the screen, user can touch down the button on the app or otoscope to capture the image.

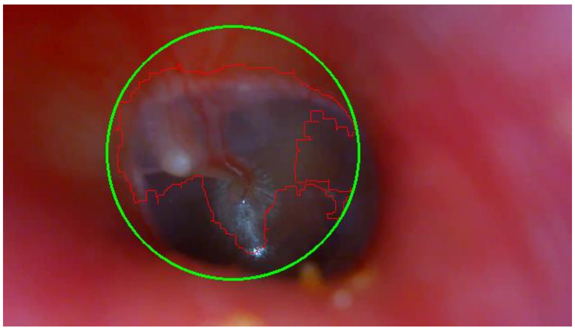

Fig. 15: Drawing the contours and circle.

6. RESULT

At the beginning, user handholds the otoscope and tries to move in the acoustic meatus to find the eardrum on the screen. With eyeball, user can check if there is any object on screen is similar to the eardrum features.

By the green circle area, user can easily distinguish the difference between the acoustic meatus and the eardrum. When the green circle maintains a fixed size for a while, means it covered the eardrum. At that time, users can touch the button to capture an appropriate image.

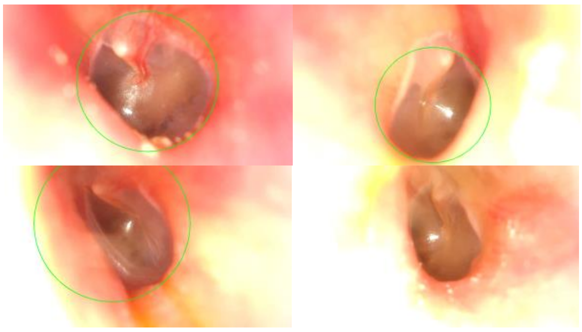

Fig. 16: Result of original image.

The Fig. 16 shows the result of original images and the Fig. 17 shows the result of balance images. With the green circle on it, we can see that the captured area on white balance image have a warm color compare with the original image.

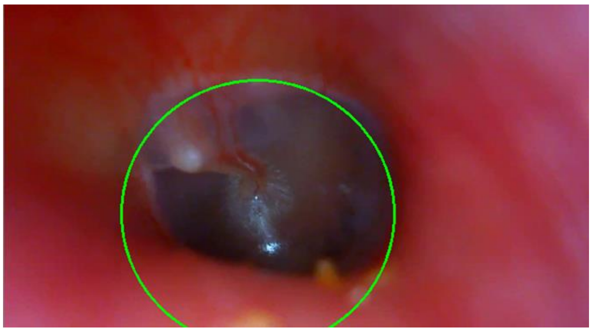

Fig. 17: Result of white balance image.

As Fig. 18 shows, the program can be used in different lighting intensity of the otoscope.

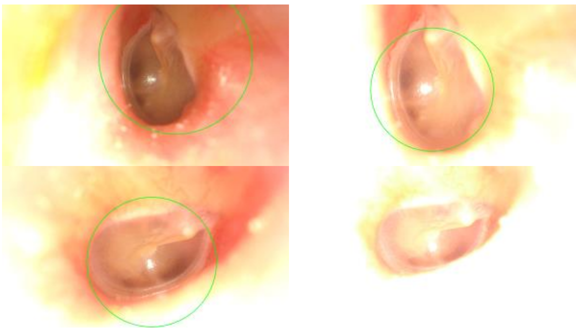

Fig. 18: Result of different brightness.

The Fig. 19 shows the result with a cap on the camera lens of otoscopes. User can reference the green circle on screen with the black area of the cap.

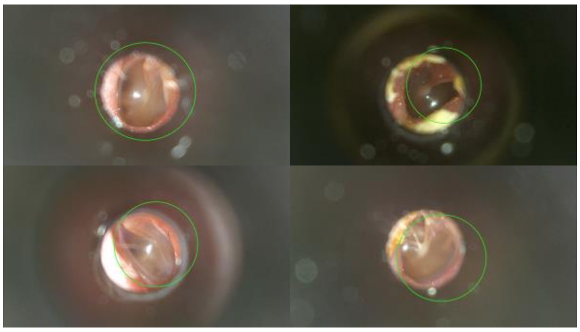

Fig. 19: Result of cap on the otoscope.

Although most of eardrums can be circled out correctly, it still has some situations that the program will miss the eardrum or circle out the wrong place.
As the Fig. 20 shows, our method circle out the ear canal or hair to be the eardrum area.

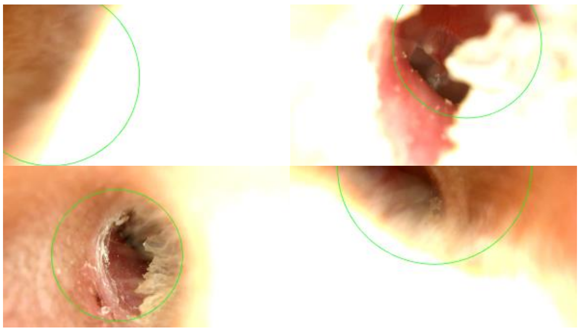

Fig. 20: Results with the ear canal or hair.

As the Fig. 21 shows, sometimes the green circle appeared in the wrong place which is the cerumen or the other barrier.

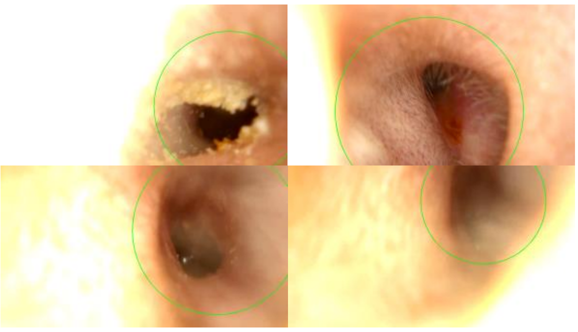

Fig. 21: Results with the cerumen or the other barrier.

Except the normal eardrum without the OM diseases, we also try our method on the different types of OM images. As the Fig. 22 shows, our method can also present a good result on the AOM image.

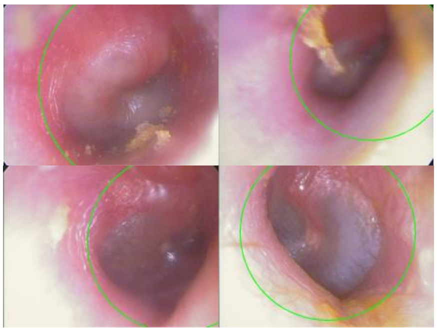

Fig. 22: Good results of AOM images.

With the good results of AOM images, there must have the failed results that is the same as normal images. As the Fig.23 shows, the green circle misses the eardrum area.

Fig. 23: Failed to circle out examples of AOM.

Also we try the OME image with our method. Because the most of areas are covered by yellower color, some eardrums can be circled out by out method.

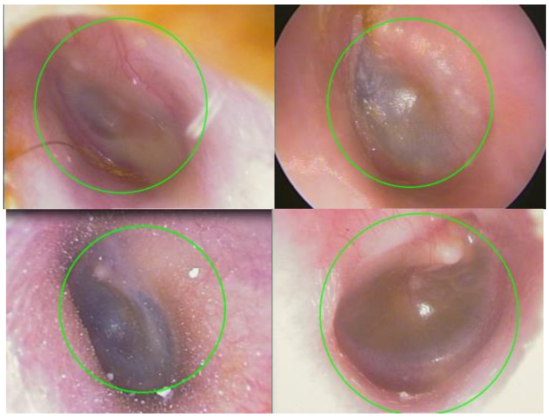

Fig. 24: Good results of OME images.

With the complex structures caused by inflammation in long time, our method has bad results or even cannot circle out an area which may be an eardrum.

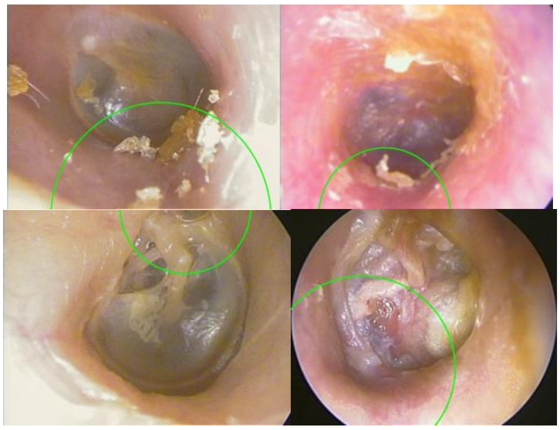

Fig. 25: Bad results caused by complex structures.

Fig. 26: Failure cases of OME.

The same as the AOM and OME, because of the longer Inflammatory reaction that results in the hollow or concave on an eardrum, the COM images is more difficult to determine the eardrum by eyeball or our method.

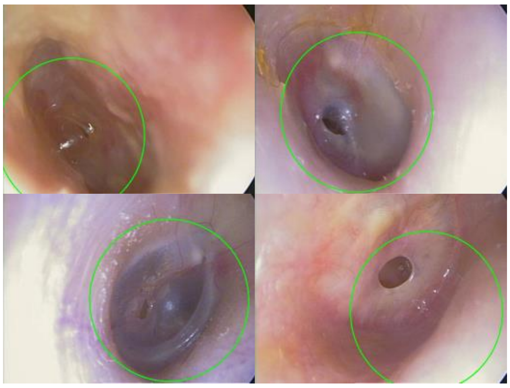

Fig. 27: Good results of COM.

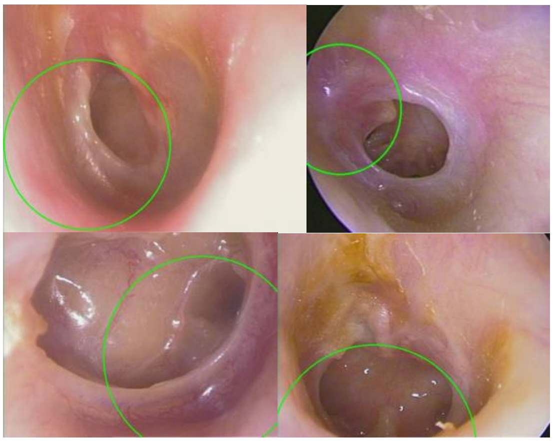

Fig. 28: Bad results caused by hollow or concave.

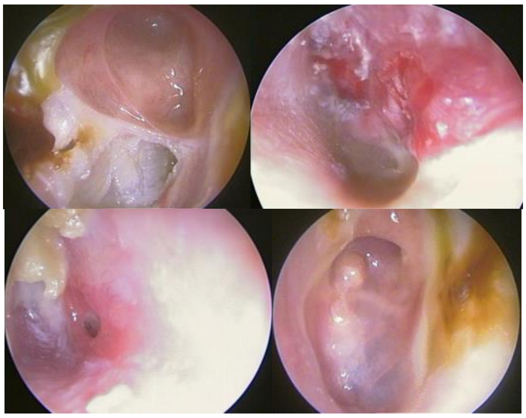

Fig. 29: Failure cases of COM.

Because of the yellow inflammatory area and red bleeding area around the eardrum, the outcomes of the COM images are bad with our method.

7. CONCLUSION

With the help of the guidance program, doctors and home users can take the appropriate image for OM analysis. According to the result of analysis and standard eardrum photos, doctors can make a more precision diagnosis and do better follow up treatments.
To make a better user experience and captured image, we will try following method:

(1) Add the arrow on screen of mobile devices during the recording to prompt the position of the eardrum.

(2) Design a tool for Otolaryngology doctors to manually circle out the eardrum to get the position and radius of each image and compare results with the program.

(3) Collect more videos and images containing different colors, ages, or other features to improve the accuracy.

REFERENCES

[1] Incidence and recurrence of acuteotitis media in Taiwan's pediatric population. Wang PC, Chang YH,Chuang LJ, Su HF, Li CY.Clinics (Sao Paulo). 2011;66(3):395-9.

[2] Takata GS, Chan LS, Morphew T, Mangione-Smith R, Morton SC, Shekelle P. Evidence assessment of the accuracy of methods of diagnosing middle ear effusion in children with otitis media with effusion. Pediatrics. 2003; 112:1379-87.

[3] Muderris T, Yazıcı A, Bercin S, Yalçıner G, Sevil E, Kırıs M. Consumer acoustic reflectometry: accuracy in diagnosis of otitis media with effusion in children. Int J Pediatr Otorhinolaryngol. 2013; 77:1771-4.

[4] Block SL, Mandel E, McLinn S, Pichichero ME, Bernstein S, Kimball S, Kozikowski J. Spectral gradient acoustic reflectometry for the detection of middle ear effusion by pediatricians and parents. Pediatr Infect Dis J. 1998; 17:560-4.

[5] https://en.wikipedia.org/wiki/Middle_ear

[6] https://en.wikipedia.org/wiki/Eardrum

[7] https://www.healthline.com/health/otitis#types

[8] https://www.sync-vision.com

[9] Canny, J., A Computational Approach To Edge Detection, IEEE Trans. Pattern Analysis and Machine Intelligence, 8(6):679–698, 1986.

[10] R. Deriche, Using Canny's criteria to derive a recursively implemented optimal edge detector, Int. J. Computer Vision, Vol. 1, pp. 167–187, April 1987.

[11] https://en.wikipedia.org/wiki/Canny_edge_detector