# Advancements in Ophthalmology: Implementing Image Processing in Matlab as a Medical Tool

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*Abstract - This research focuses on the implementation of image processing in Matlab and its role in the pre-diagnosis of eye problems, aiming to automate the process of medical image analysis in this field. The global health crisis caused by the pandemic has significantly impacted teleconsultations, particularly in our country, where the challenge lies in visualizing the patient's eye clearly through a screen. To address this, we propose the application of a single-person booth that will allow real-time capture of the patient's eye and its respective processing, so that it works as a tool that facilitates the accuracy of the doctor's diagnosis. Additionally, an infrared sensor is implemented to ensure contactless operation by detecting people entering the booth. The application of image processing techniques provides clear and accurate images, showcasing the adaptability of the project to specific situations with the integration of mechatronic and biomedical engineering knowledge.*

*Keywords-- Matlab, image processing, prediagnosis, sensor.*

## I. INTRODUCTION

Image processing (PDI) is a highly influential technological field that offers numerous benefits and impressive results. Integrating this tool into the architecture of an electronic system enhances timely diagnosis and improves the visualization of medical images in ophthalmology. Although Matlab was introduced in 1984, it remains crucial for future engineering specialists to explore and utilize all the resources it provides, especially in the current context. Deperlioglu [1] employs a range of image processing techniques, including HSV and histogram equalization, to provide specialist physicians with advanced analysis tools for predicting diabetic retinopathy. These techniques enhance retinal fundus images and achieve an impressive accuracy rate of 97%. In a similar context, Karthiyayini [2] emphasizes the absence of a specific technique for medical image analysis and diagnosis in the field of eye diseases. Their research focuses on developing a tool capable of efficiently probing retinal image data, consisting of approximately 400 samples. The images undergo preprocessing, resizing, segmentation, and extraction of RGB channels, followed by automated detection using an algorithm named EARMAM.
Liu [3] discusses the utilization of convolutional neural networks and a wide range of kernel values for classifying patterns in ocular bloodstream disease identification.

The pre-diagnosis system will be accessible to the public through a booth equipped for one person. Photos will be taken for processing in the software and subsequently sent to the ophthalmologist via a link, streamlining the diagnosis process. Despite the advantages offered by image processing, the project faces certain limitations, and comprehending the functionalities of the software presents a significant challenge. Consequently, it becomes essential to define the objectives of the implemented system and determine the specific analysis requirements to effectively utilize the relevant techniques. Additionally, assembling a prototype of the booth requires time and access to high-quality electronic devices, which can pose challenges due to the sensitivity of the components during project testing.

In [7], Gavidia provides an interesting perspective on the potential impact of image processing, highlighting its diverse applications in tomography, resonance, nuclear medicine, mammography, and other fields. Matlab software, combined with GiD assistance, enables image filtering and the identification of additional medical conditions. Further elaborating on this, Cajamarca and Chazi [6] explain that by developing an algorithm and utilizing medical photographs from a clinic, the thickness of the optic nerve can be analyzed to serve as an indicator of glaucoma and provide a presumptive diagnosis. Najeeb [4] discusses the future application of image processing in nuclear medicine, which employs radiochemicals and leverages the Matlab environment to process image properties.

## II. BACKGROUND

### A. Background of the investigation at a national level

In [5] the author makes use of an algorithmic model in C++ language and digital image processing retinographic images, which allow analyzing the severity and type of diabetic retinopathy that patients present in order to analyze whether the patient's digital retinographic sample reveals whether they have diabetic retinopathy; The first thing that was done was to determine the characteristics of said ocular problem such as shape, color and the area of presence.

[1] The author uses histogram equalization to obtain a clearer image of the pelvis, in addition to denoising the image in order to reduce the amount of intensity variations between neighboring pixels.

### B. Background of the investigation at an international level

According to [6], by applying filters to DICOM medical images, it is possible to determine the thickness of the nerve fiber in the eye, which can be indicative of glaucoma. The authors propose a presumptive glaucoma diagnosis that can be verified by medical specialists.

Additionally, [7] suggests that the combination of Matlab and the GiD medical platform can offer multifunctional capabilities for the detection of various conditions, including lung cancer, breast cancer, and even drug manipulation.

## III. DEVELOPMENT

The project considers the following hypothesis: If an image processor is implemented considering Matlab during ophthalmological teleconsultations for the presumptive prediagnosis of ocular problems, then benefits can be obtained with the automation of the process and timely treatment will be provided to patients with the help of the ophthalmologist and current technology.

To demonstrate and verify the formulated hypothesis, we operationalize it, determining the variables and indicators that are mentioned below:

Independent variable: Eye image processor with Matlab. This variable has as an indicator the abnormality in the shape of the iris, which will be determined by the diameter of the iris (di), that is, the average normal diameter of the iris is 13 mm as indicated by the pathology.

The margin of error must be less than 5%, for its calculation the following equation will be carried out:

$$\%error = \frac{|di-13|}{13} \times 100\% \qquad (1)$$

Dependent variable: Prediagnosis in ophthalmology. This variable has the following flags:

Little progress of the ophthalmological problem, which is determined based on the subtraction of the diameter of the normal iris of 13mm and that found in the tests, as indicated in (2):

$$AC = 13 - di \qquad (2)$$

Depending on the result obtained we can determine the level of damage found in the iris. That is, if the AC values are equal to 13 mm, it means that there is no damage; if AC is between 13mm and 9mm the damage is controlled; if AC is less equal to 8mm the damage is high; and if AC is equal to 1mm the damage will be irreversible.

The other indicator is the rate of patients with ocular problems (TPO), which will be determined with the patients with notorious symptoms (PSN) found in a sample of 9 people, using the following equation:

$$TPO = \frac{PSN}{TOTAL\ DE\ FAMILIARES} \times 100 \qquad (3)$$

The third indicator is the degrees of opening that the pterygium has, which will indicate the degree of pterygium found in the tests. Among which we have 4 types of opening, Grade I less than 30°, Grade II between 31° to 35°, Grade III between 51° to 70° and Grade D with a maximum opening between 71° to 90°.

By establishing the parameters, we proceed to the execution of the project for which the following materials were needed:

TABLE I
MATERIALS AND INSTRUMENTS USED:

| Materials and instruments used | |
|---|---|
| Unit | Material |
| 01 | Arduino Uno R3 |
| 01 | PIR Sensor HC-SR501 |
| 02 | 220Ω resistor |
| 02 | Leds |
| 01 | Breadboard |
| 07 | Jumpers |
| 01 | Matlab software |

To carry out the project, it was necessary to capture the steps in a block diagram, which is displayed in Fig. 1. In the first part, it shows us the beginning; when the person enters the cabin, and the camera is activated due to the PIR sensor that captures their presence. The green led automatically lights up and otherwise, the red led lights up indicating that the person is not positioned for the capture. Within the capture the image processing takes place, which is composed by the resizing of the image, conversion to grayscale, the histogram analysis which is supported by the contrast adjustment and the selection of the layer on which to focus the process.

All this will give rise to binarization, that is, obtaining the values of the image in digital or binary form. Noise is removed from the image for clarity and a set of filters are applied to analyze the parameters of the ocular image. Parallel to this process, the analysis is achieved dynamically in the processed image where anomalies in the iris or sclera are sought as a possible sign of Pterygium and cataract. Said processed information will be sent to the doctor through a command implemented in Matlab for better detail and a well-founded diagnosis.
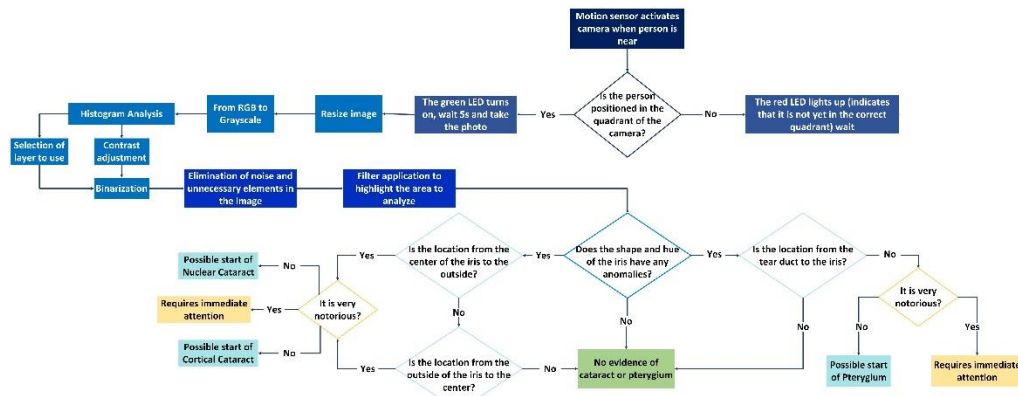


Fig. 1 Project block diagram

The development is detailed in the 5 stages detailed below:

## A. PIR Sensor signal reception

The algorithm starts with the activation in real time of the PIR sensor when detecting movement within its range, in this case produced by the patient when entering the cabin, this sensor sends a pulse 'a' which takes the value 0 or 1, at a certain time to the Arduino, a controller connected to the Matlab software. Upon receiving the pulse 'a', the process of automatically taking an image of the user's face begins.

```
clc, clear all, close all
%%% Código de recepción del Arduino a MATLAB
s= serial('COM3','BaudRate',9600); %COM3 SE EDITA DE
ACUERDO A SU SALIDA EN EL ARDUINO
fopen(s)
disp('Inicio')
data  = fscanf(s);
if data == 'a'
    disp('Inicio proceso')
```

Fig. 2 PIR Sensor signal reception code

For the physical connection we will connect the 3 pins of the PIR sensor to the Arduino with the jumpers. To visualize the reception of movement by infrared we add the green led together with a resistance of 220 ohms to prevent it from burning and we connect it to a digital port of the Arduino, for the opposite case, in other words, it doesn't detect movement, we will connect a red led with the protection resistor to connect to another digital port. The communication of the Arduino and the software is wired, which works as a power supply.

## B. Data collection

The data collection is done with the camera of a cell phone whose main camera resolution is 12 MP, enough size for an excellent quality capture, with the IP WEBCAM application we will link the cell phone with the software by typing the IP of the network to which it's connected in the corresponding line of code. So, when the PIR sensor sends the '1' signal, the algorithm will continue to capture the image of the patient's face and save it for further processing.

```
IP='192.168.1.8:8080'; %Se edita de acuerdo con la
red que esté conectada
url=strcat('http://',IP,'/shot.jpg');
Icel=imread(url);
fh_real=image(Icel);
done=false;
n=1;
while ~done
    if ~strcmp(a,'1')
      Icel=imread(url);
      set(fh_real,'CData',Icel);
      drawnow;
      filename=sprintf('Img_%d.jpg',n);
      imwrite(Icel,filename,'jpg'); %Guardar imagen
tomada
      n=n+1;
  I = imread(filename);
```

Fig. 3 Image capture code.

## C. Captured image processing

*Once the image is obtained, we proceed to carry out the pre-processing* to improve the image and have a better view of the eye.

```
%Preprocesamiento
  AInv = imcomplement(I); %Imagen invertida
  BInv = imreducehaze(AInv); %Reducción de neblina
  B = imcomplement(BInv); %Invertir resultado para
obtener la imagen mejorada
  H = histeq(B); %Mejorar el contraste mediante la
ecualización del histograma
  grayImage = rgb2gray(H); %Convertir la imagen RGB
a escala de grises
```

Fig. 4 Image preprocessing code.

Then we proceed to cut out both eyes, using the "Cascade" face detector.

```
%Detecta los ojos de la imagen
EyeDetect=vision.CascadeObjectDetector('EyePairBig')
; %Detección del par de ojos
bboxeyes = EyeDetect(grayImage);
I_eye=insertObjectAnnotation(grayImage,'rectangle',b
boxeyes,'Ojos'); %Cuadro de detección de ojos
etiquetado
figure (1)
imshow(I_eye); title('Detección de ojos');

%bbxeyes [x y width height] (Zona incluyendo el par
de ojos)
bboxeyeshalf=[bboxeyes(1,1),bboxeyes(1,2),bboxeyes(1
,3)/3,bboxeyes(1,4)];
%Recortamos los dos ojos
leftEyeImage = imcrop(I_eye,bboxeyeshalf(1,:));
leftEyeImage = imadjust(leftEyeImage); %Recorte del
ojo izquierdo
rightEyeImage =
imcrop(I_eye,[bboxeyes(1,1)+(2*bboxeyes(1,3)/3),bbox
eyes(1,2),bboxeyes(1,3)/3,bboxeyes(1,4)]);
rightEyeImage = imadjust(rightEyeImage); %Recorte
del ojo derecho
```

Fig. 5 Eye pair detection code.

Once the pair of eyes was obtained separately, we binarized the images, the level of binarization is obtained from the histograms of the pair of eyes.

```
%Binarización iris
BWi=im2bw(leftEyeImage,0.25); %Binarización del ojo
izquierdo con un valor umbral de 0.25
BWd=im2bw(rightEyeImage,0.37); %Binarización del ojo
derecho con un valor umbral de 0.37
```

Fig. 6 Code of the binarization of the pair of eyes.

When carrying out the binarization we find that there are gaps, so we proceed to fill them with the imfill function, which equals the pixels within the area to 0.

```
%Relleno de huecos
BWi=BWi==0;
BWd=BWd==0;
BWi=imfill(BWi,'holes');
BWd=imfill(BWd,'holes');
```

Fig. 7 Gap filling code.

To remove eyelash trails and other unnecessary pixels, we identify its area using properties and define a range between 0 and 2300 for the iris.

```
%Eliminación de píxeles innecesarios en el iris

[L Ne]=bwlabel(BWi); %identifica los objetos
presentes en la imagen
%Calcular propiedades de los objetos presentes en la
imagen
propied=regionprops(L,'basic'); %cálculo de
propiedades-iris izquierdo
hold on
%Buscar Áreas menores a 2300
s=find([propied.Area]<2300);
%Eliminar Áreas menores a 2300
for n=1:size(s,2)
    caja1=round(propied(s(n)).BoundingBox);

BWi(caja1(2):caja1(2)+caja1(4),caja1(1):caja1(1)+caj
a1(3))=0;
end

[L1 Ne]=bwlabel(BWd); %identifica los objetos en el
iris derecho
propied1=regionprops(L1,'basic');  %propiedades-iris
derecho
s1=find([propied1.Area]<23000); %Busca áreas menores
a 2300
for n=1:size(s1,2)
    caja1=round(propied1(s1(n)).BoundingBox);

BWd(caja1(2):caja1(2)+caja1(4),caja1(1):caja1(1)+caj
a1(3))=0;
end
```

Fig. 8 Code for removing unnecessary pixels.

Finally, we apply edge detection with sobel for a better appreciation of the iris and we conclude if it is being affected or not, this will be reflected in the shape of the iris, since if it presents a deformation, it will indicate the presence of a pterygium or cataract. For a better visualization of the last exposed, a circular frame was added establishing detection ranges by radio distance.

```
%Detección de bordes con sobel
%Bordes en el ojo izquierdo
BW1i = edge(BWi,'sobel');
%Bordes en el ojo derecho
BW1d = edge(BWd,'sobel');
```

Fig. 9 Code for edge detection.

For a better appreciation of the contours of the iris, the edges detected on the original image are shown, in addition to the circle that represents a normal iris. For this, some modifications are made in the Matlab show image command. The compendium of results produced by the program is saved in the assigned folder so that the doctor can later review it and issue a diagnosis about the condition of his patient.

```
%Círculo del iris
figure(2)
imshow(BWi);
d=imdistline; %Determinar el rango de rádio de
detección
figure(3)
[centers, radii]=imfindcircles(BW1i,[20 40]);
%Encuentra los círculos en ese rango
%Muestra los círculos encontrados en el ojo
izquierdo y los remarca en color rojo
subplot(1,2,1), imshow(leftEyeImage);
viscircles(centers, radii,'Edgecolor','r');
title('Marco del ojo izquierdo')
hold on
```

```
%Marca el borde detectado sobre la imagen original
para una mejor visualización
    B=bwboundaries(BW1i);%bw
  for k=1:length(B)
    boundary=B{k};

plot(boundary(:,2),boundary(:,1),'y','LineWidth',2)
end
  hold off
[centers, radii]=imfindcircles(BWd,[24 70]);
%Encuentra los círculos en ese rango
%Marca el borde detectado sobre la imagen original
en color amarillo
subplot(1,2,2), imshow(rightEyeImage);
viscircles(centers, radii,'Edgecolor','r');
title('Marco del ojo derecho')
hold on
%Marca el borde detectado sobre la imagen original
en color amarillo
    B=bwboundaries(BW1d);%bw
  for k=1:length(B)
    boundary=B{k};

plot(boundary(:,2),boundary(:,1),'y','LineWidth',2)
end
  hold off

fprintf('file:///C:/Users/paciente/html/PROYECTO.htm
l') %crea un link donde pueden ver los resultados
del PDI, cambiar por la ruta donde se desea guardar

end
    if strcmp(a,'q')
        done=true;
        return
    end
end
end
fclose(s) %Fin del bucle
```

Fig. 10 Code to show the final processed image.

### D. Result of processed image

To meet the objectives of the project, 2 samples were taken to show the correct functioning of the code.
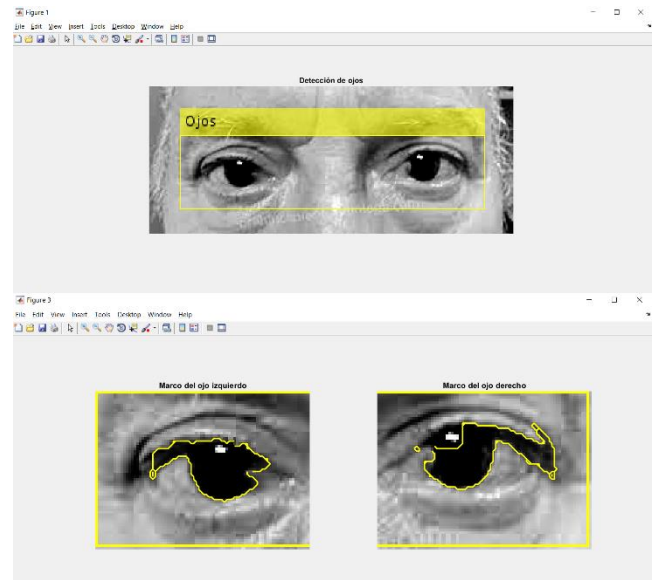


Fig. 12 Result of taking an eye with Pterygium.

Fig. 12 shows the shot of an adult person, where when processing the image, the presence of pterygium in both eyes is evident; This is concluded by the deformation of the edge of the iris since it is not completely circular, since it presents a

deformation produced by the flesh that goes from the tear duct of the eye to the iris.
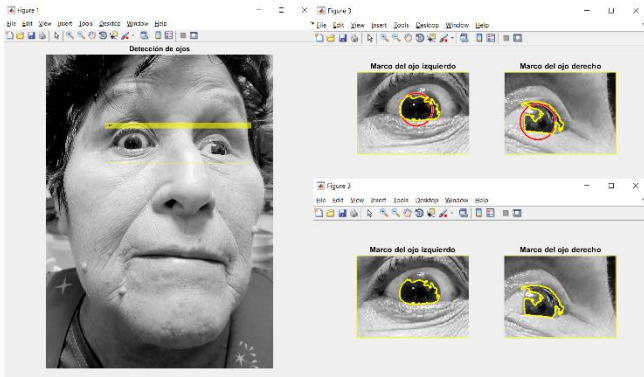


Fig. 13 Result of taking an eye with Cataract.

In Fig. 13, an elderly woman is observed, showing signs of cortical cataract in the left eye; this is evidenced by the irregular shape of the iris, and it is determined that it is of a cortical type because it goes from the outside of the iris to the inside. In the pre-processing it can be determined that the values in the histogram are consistent with what was stated under the indicators of the variables in the investigation, since on the x axis we have values $\leq 250$ and on the y axis, we have values 6000 and 8000. In addition, the operation of the PIR sensor in simulation does not present difficulties when executing the code.

As a result of the project, the rate of patients with notorious symptoms tested is 28.5%. This is obtained from (2). Said patients present advanced age and signs of cataract and pterygium due to deformation of the iris during processing.

The percentage of error reached in the tests is expected because it does not exceed 5%, since it is between 2% and 3%, which indicates the efficiency of the processing.

In accordance with (3), which highlights the limited advancements in the field of ophthalmology, our study has confirmed that the sample of 30 patients falls within the category of controlled damage. Regarding the validation process, the tests were successfully conducted on 20 patients, demonstrating that the algorithm exhibits high sensitivity and can be further modified for diverse applications and purposes.

*E. Cabin layout*

For a future implementation of the project, the cabin was designed in Autodesk Inventor with real-scale millimeter measurements in which the remote pre-diagnosis would be carried out.

For the design, it has been considered to add an inclusive ramp for the disabled, so that everyone can have access to this tool. In addition, a long LED spotlight was placed to obtain high-quality images in the processing, as well as an Oled screen so that the patient can see in real time if they are looking correctly at the camera to avoid wiring. It is suggested to implement a web or wireless camera Regarding the ramp, it requires a slope that is calculated by (4) and under the respective standards, having an angle of inclination of less than 12%.
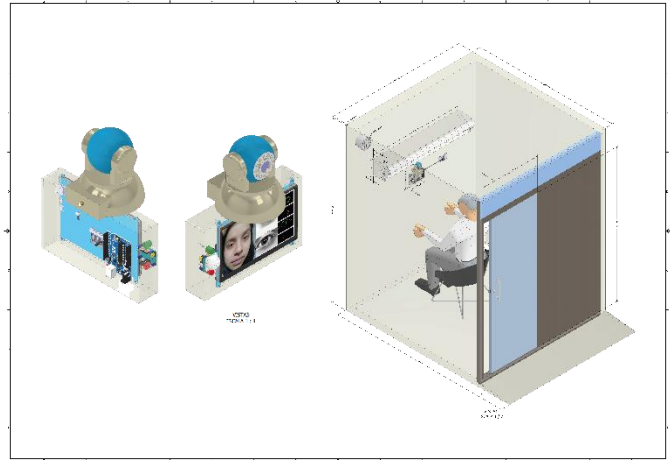
$$\%pendiente = \frac{h}{d} \times 100 \tag{4}$$



Fig. 13 Layout of the cabin

## IV. CONCLUSIONS

The implementation of processing techniques in ophthalmology enables us to obtain a clearer picture and provide pre-diagnoses, which still require confirmation by a specialist. However, given the current state of emergency, this implementation can be adopted.

Constructing the cabin to scale presents a significant challenge, but it does not affect the accuracy of the results. The utilization of the PIR sensor ensures precise detection angles and guarantees its effectiveness in enclosed spaces such as the cabin. Moreover, the project is accessible and cost-effective, while also eliminating direct contact between the patient and doctor.

Throughout the project, we encountered certain limitations; nevertheless, with the aid of cutting-edge technology, we were able to overcome them and maintain the project's continuous progress. Furthermore, this is not the end of the project, as it can be further enhanced with various tools such as layered energy analysis, signal capture, and advanced methods of biomedical and mechatronic engineering. This will enhance its versatility and enable adaptation to specific situations, aligning with its intended objectives.

## ACKNOWLEDGMENT

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