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وزارة التعليم العالي والبحث العلمي

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قسم الاعلام الالي

# Master Thesis in Computer Science

**Presented by**

**SOUILA Abir**

**Specialty :Intelligent Computer Systems**

## Theme

## The Early Diagnosis Of Diabetic Retinopathy

**Defence on :**30/06/2022

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# Abstract

*Diabetic retinopathy is the leading cause of blindness in the world population. Early detection and appropriate treatment can significantly reduce the risk of loss of sight.*

*Medical authorities recommend an annual fundus examination for patient's diabetics. Several screening programs for diabetic retinopathy in the world have been deployed to implement this recommendation.*

*Our goal is to realize the idea and the principle of these projects in order to facilitate the detection of this disease, using artificial intelligence and the latest technologies of it. Our application allows to capture retinal photos using 'a microscopic lens, to process them via several operators depending on the morphology mathematical after a filtering stage, by exploiting the algorithms then storing in a local or remote MySQL database. The app also offers a small service and facilitates the task of the ophthalmologist by allowing the consultation of patient files remotely.*

***Keywords:*** *Diabetic retinopathy; screening; fundus; tele-ophthalmology; SVM; CNN.*

# Résumé

*La rétinopathie diabétique est la principale cause de cécité dans la population mondiale. Une détection précoce et un traitement approprié peuvent réduire considérablement le risque de perte de la vue.*

*Les autorités médicales recommandent un examen annuel du fond d'œil pour les patients diabétiques. Plusieurs programmes de dépistage de la rétinopathie diabétique dans le monde ont été déployés pour mettre en œuvre cette recommandation.*

*Notre objectif est de concrétiser l'idée et le principe de ces projets afin de faciliter la détection de cette maladie, en utilisant l'intelligence artificielle et les dernières technologies de celle-ci Notre application permet de capturer des photos rétiniennes à l'aide d'une lentille microscopique, de les traiter via plusieurs opérateurs en fonction de la morphologie mathématique après une étape de filtrage, en exploitant les algorithmes puis stocker dans une base de données MySQL locale ou distante. L'appli propose aussi un petit service et facilite la tâche du médecin ophtalmologiste et cela en permettant la consultation des dossiers patients à distance.*

***Mots clés :*** *Rétinopathie diabétique ; dépistage; fond; télé-ophtalmologie; SVM ; CNN.*

# ملخص

/اعتلال الشبكية السكري هو السبب الرئيسي للعمى بين سكان العالم. يمكن للاكتشاف المبكر والعلاج المناسب أن يقلل بشكل كبير من خطر فقدان البصر.

توصي السلطات الطبية بإجراء فحص قاع سنوي لمرضى السكر. تم نشر العديد من برامج الفحص لاعتلال الشبكية السكري في العالم لتنفيذ هذه التوصية

هدفنا هو تحقيق فكرة ومبدأ هذه المشاريع من أجل تسهيل الكشف عن هذا المرض باستخدام الذكاء الاصطناعي وأحدث التقنيات الخاصة به.يتيح تطبيقنا التقاط صور شبكية العين باستخدام 'عدسة مجهرية ، لمعالجتها عبر عدة عوامل تعتمد على التشكل حسابية بعد مرحلة التصفية ، من خلال استغلال الخوارزميات ثم تخزينها في قاعدة بيانات MySQL محلية أو بعيدة. يقدم التطبيق أيضًا خدمة صغيرة ويسهل مهمة طبيب العيون من خلال السماح باستشارة ملفات المريض عن بُعد

**الكلمات الرئيسية:** اعتلال الشبكية السكري. تحري؛ قاع. طب العيون عن بعد. ذكري المظهر؛ SVM, CNN

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# Abreviations list

- **AI**: artificial intelligence
- **ARMD**: Age-Related Macular Degeneration
- **CNN**: Convolutional Neural Network
- **DEU**: Decision Engine Unit
- **DR**: Diabetic Retinopathy
- **HCS**: Health Care System
- **OAD**: Object-Oriented Analysis and Design
- **OMG**: Object Management Group
- **RSD**: reference standard diagnosis
- **SVM**: Support Vector Machine
- **UI**: User Interface
- **UML**: Unified Modeling Language
- **VA**: Veterans Affairs

# General Introduction

Some eye conditions, such as diabetic retinopathy, are more treatable when they are asymptomatic. The problem is that sometimes you have to wait months before you can see an ophthalmologist, which can lead to expensive travel and other related costs. Delayed mode artificial intelligence provides timely eye care, making it easier to detect and treat eye conditions before irreversible vision loss occurs. For this, we have considered designing an application to monitor the diabetic patient, who is at risk of having diabetic retinopathy, which will be described in detail later. The principle of our application is to help ophthalmologists to detect this disease. The work carried out within this framework and the results obtained are grouped together in a dissertation organized as follows:

Chapter 1 is divided by nature into two parts. The first describes the biomedical framework, the anatomy of the fundus eye, in particular the retina and its main elements, as well as the anomalies that affect the eye, of which we will detail the disease of diabetic retinopathy, its clinical signs and different stages, and we will show the importance of early detection. When the second part consists on presenting a state of the art on the methods proposed before, to remedy the problem of early detection of DR by using IA, and specifying the used technologies.

In chapter 2, we will present the overall architecture of the proposed solution, the hybridized algorithm, as well as the design.

The last chapter will discuss the implementation of our application, the different working environments and programming tools, as well as the image processing used techniques, finally, we will detail our application while illustrating its interfaces.

We will end this manuscript with a general conclusion and some perspectives.

# Chaptre 1 : State of the art

## 1. Introduction

During their lifetime, more than one on three diabetic patients will develop diabetic retinopathy (DR), the most common microvascular complication of the disease and a leading cause of blindness worldwide.

Telemedicine and artificial intelligence (AI) are developing to allow the greatest number of patients to access screening and help them to deal with the major expansion of the disease, facing a declining medical demography, very unequal from one region to another. These tools must now be integrated into the DR screening and follow-up process.

The objective of this chapter is firstly; to make a descriptive analysis of the eye anatomy, diabetes as well as its complications especially diabetic retinopathy ; secondly we will make a qualitative analysis of the current works done by the scientific community for screening diabetic retinopathy in order to suggest ways of improvement.

## 2. Eye anatomy

The human eye is one of the important sensory organs of the human body. It is very sensitive and exposed to various diseases, thus protection and prevention is necessary to keep the eye safe and healthy.

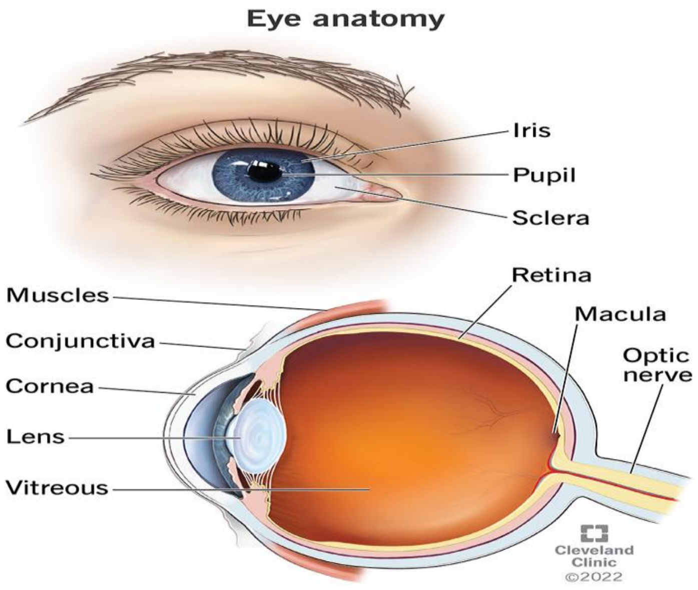



Figure 1.1: Eye anatomy [1]

The eyeball has three coats as shown on figure 1.1

- **External fibrous coat**

The anterior, transparent part of the eyeball is called cornea. This refracts the rays of light into the eye. Cornea further extends with a membranous structure called conjunctiva. The connecting area of cornea and conjunctiva is limbus. External fibrous coat is formed of cornea and sclera.

- **Middle vascular coat**

This coat is formed by the iris, ciliary body and choroid (anterior to posterior). This coat is vascular and pigmented, underlying the sclera.

- **Internal nervous coat**

Internal nervous coat is formed of retina. The retina receives an inverted image of the objects seen. These images are conducted to the brain through a nerve called the optic nerve, which is connected at the posterior end of the eyeball.

## 2.1. Parts of the human eye:

The parts of the eye include:

- **Iris**, the colored area of your eye. Depending on your eye color, the iris might be any shade of blue, green, hazel or brown.
- **Cornea**, a clear layer that extends over the iris. Water and collagen make up the cornea. Your tears protect your cornea and keep it lubricated.
- **Pupil**, the black circle which is an opening or window in the middle of your iris. It expands and contracts to control how much light gets into your eye.
- **The sclera**, the white parts of your eye that surround the iris.
- **Conjunctiva**, a clear, thin tissue that covers the sclera and lines the inside of your eyelids.
- **Lens**, which sits behind the pupil. It focuses the light that comes into your eye and sends light to the back of your eye.
- **Retina**, a collection of cells that line the inside of the back of your eye. Part of your nervous system, the retinas sense light and convert it into electrical impulses or neural signals. The retina has rods (cells that help you see in low light) and cones (cells that detect color).
- **Macula**, a small area that's part of the retina. It's responsible for central vision and helping you see fine details and color.
- **Optic nerve**, which is behind the retina. It carries signals from the retina to your brain which then interprets that visual information to tell you what you are seeing.
- **Muscles**, which control your eye's position and movement, how much light gets into your eye and your eyes' ability to focus.

- **Vitreous**, a transparent gel that fills your entire eye. It protects and maintains the shape of the eye.

### 2.2. Function of the eye:

The different parts of our eye work together to help us see images and send visual information to the brain. This process all happens extremely quickly. When we look at an object:

1. Light enters the eye through the cornea and goes to the lens. The pupil gets bigger and smaller to control the amount of light that gets into the eye.
2. The cornea and lens refract (bend) the light to bring what we are seeing into focus.
3. Light reaches the retina at the back of the eye, and the retina changes the images into electrical impulses or signals.
4. The optic nerve transfers these signals to the part of the brain that's responsible for vision (visual cortex). The optic nerve carries signals from both eyes at once.
5. The brain interprets what we have seen. It combines the visual information from both eyes and brings it all together into one clear image.

There are hundreds of conditions, disorders, diseases and injuries that affect the eyes. Some conditions, such as uveitis, cause eye pain. Others can lead to low vision or vision loss. In the next part, we will present one of the main causes of eye dysfunction, which is diabetes [2]

## 3. Diabetes

### 3.1. Definition

Diabetes is when your blood glucose, also called blood sugar, is too high. Blood glucose is the main type of sugar found in your blood and your main source of energy.

Glucose comes from the food we eat and is also made in our liver and muscles. Our blood carries glucose to all of our body's cells to use for energy.

Our pancreas—an organ, located between the stomach and spine, that helps with digestion—releases a hormone it makes, called insulin, into our blood. Insulin helps our blood carry glucose to all our body's cells. Sometimes our body doesn't make enough insulin or the insulin doesn't work the way it should. Glucose then stays in our blood and doesn't reach our cells. Our blood glucose levels get too high and can cause diabetes or prediabetes.

Over time, having too much glucose in our blood can cause health problems.

## 3.2. Type of diabetes:

The three main types of diabetes are type 1, type 2, and gestational diabetes. People can develop diabetes at any age. Both women and men can develop diabetes.

### 3.2.1. Type 1 Diabetes

Type 1 diabetes, which used to be called juvenile diabetes, develops most often in young people; however, type 1 diabetes can also develop in adults. In type 1 diabetes, our body no longer makes insulin or enough insulin because the body's immune system, which normally protects us from infection by getting rid of bacteria, viruses, and other harmful substances, has attacked and destroyed the cells that make insulin.

Treatment for type 1 diabetes includes:

- Taking shots, also called injections, of insulin.
- Sometimes taking medicines by mouth.
- Making healthy food choices.
- Being physically active.
- Controlling our blood pressure levels. Blood pressure is the force of blood flow inside our blood vessels.
- Controlling our cholesterol levels. Cholesterol is a type of fat in our body's cells, in our blood, and in many foods.

### 3.2.2. Type 2 Diabetes

Type 2 diabetes, which used to be called adult-onset diabetes, can affect people at any age, even children.

However, type 2 diabetes develops most often in middle aged and older people. People who are overweight and inactive are also more likely to develop type 2 diabetes.

Type 2 diabetes usually begins with insulin resistance—a condition that occurs when fat, muscle, and liver cells do not use insulin to carry glucose into the body's cells to use for energy. As a result, the body needs more insulin to help glucose enter cells. At first, the pancreas keeps up with the added demand by making more insulin. Over time, the pancreas doesn't make enough insulin when blood sugar levels increase, such as after meals. If our pancreas can no longer make enough insulin, you will need to treat your type 2 diabetes.

Treatment for type 2 diabetes includes

- Using diabetes medicines

- Making healthy food choices
- Being physically active
- Controlling our blood pressure levels
- Controlling our cholesterol levels

### 3.2.3. Gestational Diabetes

Gestational diabetes can develop when a woman is pregnant. Pregnant women make hormones that can lead to insulin resistance. All women have insulin resistance late in their pregnancy. If the pancreas doesn’t make enough insulin during pregnancy, a woman develops gestational diabetes.

Overweight or obese women have a higher chance of gestational diabetes. Also, gaining too much weight during pregnancy may increase the likelihood of developing gestational diabetes.

Gestational diabetes most often goes away after the baby is born. However, a woman who has had gestational diabetes is more likely to develop type 2 diabetes later in life. Babies born to mothers who had gestational diabetes are also more likely to develop obesity and type 2 diabetes.

## 3.3. Complications of diabetes:

The complications associated to diabetes all have a common cause, which is an excess of glucose in the blood, if it is at such a high level over time it has adverse effects on many organs of the body, mainly:

- kidneys (Nephropathy)
- Eyes (Retinopathy)
- Nervous system (Neuropathy)
- Heart (Heart attack)
- Blood vessels (arterial hypertension, …)

Diabetes is also associated with other complications such as:

- sleep apnea
- capsulitis
- erectile dysfunction
- yeast infections
- urinary tract infections
- periodontal disease

With these complications, the patient with the disease finds himself with a completely new way of life to manage every day.

On the next section we will focus on one of these complications which is retinopathy. [3]

## 4. Diabetic retinopathy

Diabetic Retinopathy (DR) can result from genetic and environmental factors and is characterized by a permanent excess of sugar in the blood. Faced with an incredible increase in the number of patients, experts now speak of an epidemic. Diabetes attacks the blood vessels and in particular those of the retina, which is highly vascularized. Diabetic retinopathy remains today the leading cause of blindness in young people and visually impaired people. This is due to its often being treated too late. Indeed, DR is a silent assignment for many years. Only screening carried out regularly, in accordance with the recommendations of good clinical practice, can enable early diagnosis and treatment [4]

## 5. Diagnosis

### 5.1. Circumstances of discovery Diabetic retinopathy (DR)

Can be revealed by a decrease in visual acuity. This is usually late and occurs only after a long period of silent evolution of diabetic retinopathy, triggered by complications of DR. Diabetic retinopathy must be detected by the systematic ophthalmological examination carried out when diabetes is discovered or during the annual ophthalmological monitoring of any diabetic.

### 5.2. Diagnosis of diabetic

Diagnosis of DR is based on biomicroscopic examination of the fundus after pupillary dilation, supplemented by fundus photographs.

However, given the large numbers of people affected worldwide, there are not sufficient specialists globally to screen everyone at risk. The shortfall is particularly acute in developing countries, including India, and many countries in Asia and Africa.  In addition, many affected people live in remote areas with little or no access to clinics and screening facilities. This makes Diabetic Retinopathy a global healthcare challenge that needs urgent resolution[5].

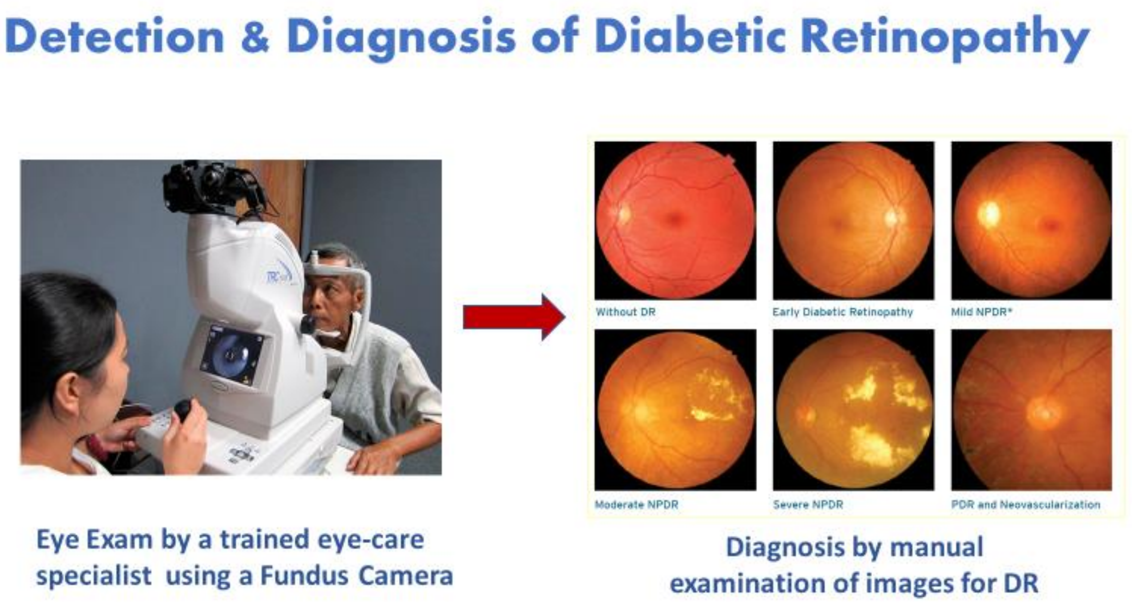



Figure 1.2. Diagnosis of retinopathy [6]

## 6. DR Screening

DR prevention focuses on ongoing monitoring and early treatment. These preventive actions can delay or stop the progression of these diseases, prevent blindness and improve the quality of life. Since there are no salient symptoms in the early stages of Diabetic Retinopathy (DR) and Age-Related Macular Degeneration (ARMD), and the number of symptoms and severity essentially increase over time, cost-effective screening of large populations is needed. Screening is a secondary preventive action that aims to find and treat conditions that have already occurred, but have not reached a stage that requires medical attention. Studies have revealed that older people and people who suffer more from diabetes regularly attend a screening session. By the way, the progression of these diseases is reviewed at least once in 1-3 years, which results in an increasing amount of information for the examination. This is why the development of a remote screening system is necessary

As we said above, this pathology has not ceased to develop and the major cause is the lack of experienced specialists to diagnose the disease at an early stage. That’s why scientists thought about an automatic solution that can detect it early.

In what follows, we will present a state of the art on the work carried out in the context of this issue in order to see more clearly.

# 7. Related works

After analysis of several articles in this field, we found that we could divide this research into two main categories:

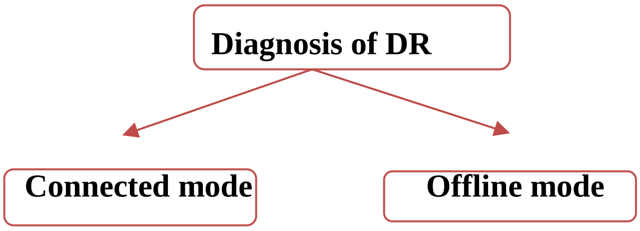



Figure 1.3. Principal categories of diagnosis of DR

## 7.1. Connected mode:

Since the early 2000s, many works on the automatic diagnosis of elementary DR lesions have been published [7] Based on machine learning, automatic detection algorithms for retinal microaneurysms, retinal microhemorrhages and exudates have been developed.

It is with convolutional deep neural networks (CNN or ConvNet) that AI took off from 2010. Their greatest performance is linked to the fact that they are able to extract the characteristics of lesions from images on their own, then to classify them, without manual intervention. This allows, for DR, a more global diagnosis; they can diagnose its presence and grade its severity. Among several projects we can cite those one:

**A. Automated Diagnosis of Plus Disease in Retinopathy of Prematurity Using Deep Convolutional Neural Networks :**

A deep convolutional neural network was trained using a data set of 5511 retinal photographs. Each image was previously assigned a reference standard diagnosis (RSD) based on consensus of image grading by 3 experts and clinical diagnosis by 1 expert (ie, normal, pre–plus disease, or plus disease). The algorithm was evaluated by 5-fold cross-validation and tested on an independent set of 100 images. Images were collected from 8 academic institutions participating in the Imaging and Informatics in ROP (i-ROP) cohort study. The deep learning algorithm was tested against 8 ROP experts, each of whom had more than 10 years of clinical experience and more than 5 peer-reviewed publications about ROP. Data were collected from July 2011 to December 2016. Data were analyzed from December 2016 to September 2017.

Receiver operating characteristic analysis was performed to evaluate performance of the algorithm against the RSD. Quadratic-weighted κ coefficients were calculated for ternary classification (ie, normal, pre–plus disease, and plus disease) to measure agreement with the RSD and 8 independent experts.

Results of the 5511 included retinal photographs, 4535 (82.3%) were graded as normal, 805 (14.6%) as pre–plus disease, and 172 (3.1%) as plus disease, based on the RSD. Mean (SD) area under the receiver operating characteristic curve statistics were 0.94 (0.01) for the diagnosis of normal (vs pre–plus disease or plus disease) and 0.98 (0.01) for the diagnosis of plus disease (vs normal or pre–plus disease). For diagnosis of plus disease in an independent test set of 100 retinal images, the algorithm achieved a sensitivity of 93% with 94% specificity. For detection of pre–plus disease or worse, the sensitivity and specificity were 100% and 94%, respectively. On the same test set, the algorithm achieved a quadratic-weighted κ coefficient of 0.92 compared with the RSD, outperforming 6 of 8 ROP experts.

### B. Automated Identification of Diabetic Retinopathy Using Deep Learning:

In this study, researchers developed and evaluated a data-driven deep learning algorithm as a novel diagnostic tool for automated DR detection. The algorithm processed color fundus images and classified them as healthy (no retinopathy) or having DR, identifying relevant cases for medical referral.

A total of 75 137 publicly available fundus images from diabetic patients were used to train and test an artificial intelligence model to differentiate healthy fundi from those with DR. A panel of retinal specialists determined the ground truth for the data set before experimentation. They also tested the model using the public MESSIDOR 2 and E-Ophtha databases for external validation. Information learned in the automated method was visualized readily through an automatically generated abnormality heatmap, highlighting subregions within each input fundus image for further clinical review.

They used area under the receiver operating characteristic curve (AUC) as a metric to measure the precision–recall trade-off of the algorithm, reporting associated sensitivity and specificity metrics on the receiver operating characteristic curve.

As a result the model achieved a 0.97 AUC with a 94% and 98% sensitivity and specificity, respectively, on 5-fold cross-validation using local data set. Testing against the independent MESSIDOR 2 and E-Ophtha databases achieved a 0.94 and 0.95 AUC score, respectively.

### C. Artificial intelligence using deep learning to screen for referable and vision-threatening diabetic retinopathy in Africa: a clinical validation study:

Researchers adopted an ensemble AI model consisting of a combination of two convolutional neural networks (an adapted VGGNet architecture and a residual neural network architecture) for classifying retinal colour fundus images. They trained the model on 76 370 retinal fundus images from 13 099 patients with diabetes who had participated in the Singapore Integrated Diabetic Retinopathy Program, between 2010 and 2013, [8] In this clinical validation study, they included all patients with a diagnosis of diabetes that attended a mobile screening unit in five urban centres in the Copperbelt province of Zambia from Feb 1 to June 31, 2012. In this model, referable diabetic retinopathy was defined as moderate non-proliferative diabetic retinopathy or worse, diabetic macular oedema, and ungradable images. Vision-threatening diabetic retinopathy comprised severe non-proliferative and proliferative diabetic retinopathy. They calculated the area under the curve (AUC), sensitivity, and specificity for referable diabetic retinopathy, and sensitivities of vision-threatening diabetic retinopathy and diabetic macular oedema compared with the grading by retinal specialists.

A total of 4504 retinal fundus images from 3093 eyes of 1574 Zambians with diabetes were prospectively recruited. Referable diabetic retinopathy was found in 697 (22·5%) eyes, vision-threatening diabetic retinopathy in 171 (5·5%) eyes, and diabetic macular oedema in 249 (8·1%) eyes. The AUC of the AI system for referable diabetic retinopathy was 0·973 (95% CI 0·969–0·978), with corresponding sensitivity of 92·25% (90·10–94·12) and specificity of 89·04% (87·85–90·28). Vision-threatening diabetic retinopathy sensitivity was 99·42% (99·15–99·68) and diabetic macular oedema sensitivity was 97·19% (96·61–97·77). The AI model and human graders showed similar outcomes in referable diabetic retinopathy prevalence detection and systemic risk factors associations. Both the AI model and human graders identified longer duration of diabetes, higher level of glycated haemoglobin, and increased systolic blood pressure as risk factors associated with referable diabetic retinopathy

### D. Applying artificial intelligence to disease staging: Deep learning for improved staging of diabetic retinopathy

The retrospective study analyzed 9,939 posterior pole photographs of 2,740 patients with diabetes. Nonmydriatic 45° field color fundus photographs were taken of four fields in each eye annually at Jichi Medical University between May 2011 and June 2015. A modified fully randomly initialized GoogLeNet deep learning neural network was trained on 95% of the photographs using manual modified Davis grading of three additional adjacent photographs. We graded 4,709 of the 9,939 posterior pole fundus photographs using real prognoses. In addition, 95% of the photographs were learned by the modified GoogLeNet. Main outcome measures were prevalence and bias-adjusted Fleiss' kappa (PABAK) of AI staging of the remaining 5% of the photographs.

The PABAK to modified Davis grading was 0.64 (accuracy, 81%; correct answer in 402 of 496 photographs). The PABAK to real prognosis grading was 0.37 (accuracy, 96%).

### E. Transfer Learning for Automated OCTA Detection of Diabetic Retinopathy :

A deep-learning convolutional neural network (CNN) architecture, VGG16, was employed for this study. A transfer learning process was implemented to retrain the CNN for robust OCTA classification. One dataset, consisting of images of 32 healthy eyes, 75 eyes with diabetic retinopathy (DR), and 24 eyes with diabetes but no DR (NoDR), was used for training and cross-validation. A second dataset consisting of 20 NoDR and 26 DR eyes was used for external validation. To demonstrate the feasibility of using artificial intelligence (AI) screening of DR in clinical environments, the CNN was incorporated into a graphical user interface (GUI) platform.

With the last nine layers retrained, the CNN architecture achieved the best performance for automated OCTA classification. The cross-validation accuracy of the retrained classifier for differentiating among healthy, NoDR, and DR eyes was 87.27%, with 83.76% sensitivity and 90.82% specificity. The AUC metrics for binary classification of healthy, NoDR, and DR eyes were 0.97, 0.98, and 0.97, respectively. The GUI platform enabled easy validation of the method for AI screening of DR in a clinical environment.

#### F. A study of diabetic retinopathy classification using support vector machine :

Previous researchers have studied machine learning to propose an automatic DR classification. However, it needs to be improvised especially in terms of accuracy [9]. Hence, this work aimed to find classifier with optimal performance in the study of DR classification. This study considered three classes of diabetic patients which were patients who do not have DR (NODR), patients with non-proliferative DR (NPDR) and patients with proliferative DR (PDR), instead of focusing only on two classes (NO DR, DR). Support Vector Machine was used in this research due to the success of many classification problems that had been proposed which produced good result. The results obtained showed that SVM gave the best accuracy, 76.62% with average sensitivity of 0.8081 and average specificity of 0.8376 respectively.

## 7.2. Offline mode:

As presented before, several studies have already explored the interest of artificial intelligence (AI) in this field, with positive results, but implying the need to use professional retinophotography devices, as well as AI Internet platforms.

To facilitate screening for diabetic retinopathy, researchers opted for an offline mode solution based on the use of smartphones.

Next part, illustrates the innovative project.

#### A. Diabetic retinopathy detection in smartphone-based fundus photography using artificial intelligence:

An Indian team has developed Medios, a non-mydriatic retinophotography system via a portable mini-camera (Remidio) coupled to a smartphone, allowing firstly to take a photograph of the retina and secondly to embed an AI system not requiring the use of an Internet platform, and provides an immediate diagnosis.


Figure 1.4. Medios system. [10]

In India, in a single diabetology center, 900 patients received retinophotography images (1 photo centered on the macula and 1 photo of the nasal field) using this system. The results were compared with the analysis carried out in parallel by 5 expert ophthalmologists whose conclusions constituted the reference (or the “gold standard”).

Among the 900 examinations carried out, 252 diabetic retinopathies were identified by the machine and graded as mild (n = 51), moderate (n = 163), severe (n = 3), proliferative (n = 35) or mild edematous maculopathy. , moderate or severe (n = 12, 32 or 3; respectively). The sensitivity and specificity of the Medios system for detecting all retinal damage were 83.3 and 95.5%, respectively. The positive and negative predictive values were 87.8 and 93.6%, respectively. The sensitivity was 98.7% for the detection of retinopathies threatening the visual prognosis. The sensitivity and specificity of the Medios system have thus exceeded the minimum performance expected by the FDA (Food and Drug Administration), which has validated the use of this system for diabetic retinopathy screening in the United States [11].

## 7.3. Results validation research:

With rising global prevalence of diabetic retinopathy (DR), automated DR screening is needed for primary care settings. Two automated artificial intelligence (AI)–based DR screening algorithms have U.S. Food and Drug Administration (FDA) approval [12]. Several others are under consideration while in clinical use in other countries, but their real-world performance has not been evaluated systematically. A lot of publication, studied the performance of several automated AI-based DR screening algorithms against human graders when analyzing real-world retinal imaging data.

Among which, we mentioned:

**A. Multicenter, Head-to-Head, Real-World Validation Study of Seven Automated Artificial Intelligence Diabetic Retinopathy Screening Systems:**

This was a multicenter, noninterventional device validation study evaluating a total of 311,604 retinal images from 23,724 veterans who presented for teleretinal DR screening at the Veterans Affairs (VA) Puget Sound Health Care System (HCS) or Atlanta VA HCS from 2006 to 2018. Five companies provided seven algorithms, including one with FDA approval, that independently analyzed all scans, regardless of image quality. The sensitivity/specificity of each algorithm when classifying images as referable DR or not were compared with original VA teleretinal grades and a regraded arbitrated data set. Value per encounter was estimated.

As result, although high negative predictive values (82.72–93.69%) were observed, sensitivities varied widely (50.98–85.90%). Most algorithms performed no better than humans against the arbitrated data set, but two achieved higher sensitivities, and one yielded comparable sensitivity (80.47%, $P = 0.441$) and specificity (81.28%, $P = 0.195$). Notably, one had lower sensitivity (74.42%) for proliferative DR ($P = 9.77 \times 10^{-4}$) than the VA teleretinal graders. Value per encounter varied at $15.14–$18.06 for ophthalmologists and $7.74–$9.24 for optometrists

**B. Artificial intelligence-enabled screening for diabetic retinopathy: a real-world, multicenter and prospective study:**

The study was prospectively conducted at 155 diabetes centers in China. A non-mydriatic, macula-centered fundus photograph per eye was collected and graded through a deep learning (DL)-based, five-stage DR classification. Images from a randomly selected one-third of participants were used for the DL algorithm validation.

In total, 47 269 patients (mean (SD) age, 54.29 (11.60) years) were enrolled. 15 805 randomly selected participants were reviewed by a panel of specialists for DL algorithm validation. The DR grading algorithms had a 83.3% (95% CI: 81.9% to 84.6%) sensitivity and a 92.5% (95% CI: 92.1% to 92.9%) specificity to detect referable DR. The five-stage DR classification performance (concordance: 83.0%) is comparable to the interobserver variability of specialists (concordance: 84.3%). The estimated prevalence in patients with diabetes detected by DL algorithm for any DR, referable DR and vision-threatening DR were 28.8% (95% CI: 28.4% to 29.3%), 24.4% (95% CI: 24.0% to 24.8%) and 10.8% (95% CI: 10.5% to 11.1%), respectively. The prevalence was higher in female, elderly, longer diabetes duration and higher glycated hemoglobin groups.

C. **Evaluation of Performance of Decision Tree, Support Vector Machine and Probabilistic Neural Network Classifiers in a Mobile Based Diabetes Retinopathy Detection System:**

The focus of this work is to evaluate the performance of Decision Tree (DT), Support Vector Machine (SVM) and Probabilistic Neural Network (PNN) Classifiers in Diabetes Retinopathy Detection.

Corresponding results showed SVM has the best classification strength by achieving Recognition Accuracy (RA) of 98.50%, while PNN and DT achieved RA of 97.60% and 89.20% respectively. In terms of False Acceptance Rate (FAR) and False Rejection Rate (FRR), SVM has the least values of 7.21, 8.10 while DT and PNN showed 11.10, 9.30 and 13.21, 10.10 respectively[13].

## 8. Synthesis

In the previous part (Related works) we mentioned certain works undertaken, in order to diagnose or detect the pathology, and this thanks to many approaches, which several of them (theoretically available) allowed automatic diagnosis of DR with excellent performance, are therefore.

Until now, we found that the most successful approach resides within the use of deep learning algorithms; especially Convolutional Neural Networks (CNN). However, it is limited in several ways. First, the current accuracy of DR is still low and need to be improvised to the best of our knowledge. The work [14] yield the highest accuracy, but with an overall accuracy 92.76%, it leaves room for improvement for DR classification. Besides, a few studies [15] considered small number of instances in the dataset which are not enough to build a good classifier. In addition, very little work have been done with regards to DR classification focusing on three classes of DR (NO DR, NPDR, PDR). Most of the studies done previously focused only on two of the classes (NO DR, DR).

For that reason, the most of them are classifying using retinal imaging which is a classification technique performed based on the abnormalities found on retinal fundus image such as exudates, micro aneurysm, hemorrhages and also blood vessels. Although the retinal imaging technique facilitate early detection of DR, they required additional equipment, which is quite cost-prohibitive or sometimes unavailable especially in rural areas.

On the other hand, several DR classifiers, especially using Support Vector Machine (SVM) classifier that address the limitations of the extant literature, with the motivation to improve their results, have been developed using clinical variables as an alternative to retinal imaging. However, there is still some space for improvement especially in the accuracy of the classifiers.

Thus, we propose a new framework, basing on a hybridization strategy, merging the most used algorithms, which are CNN and SVM to achieve the highest accuracy rates among all other common classification algorithms in the area.

## 9. Conclusion

In this chapter, we did a study on artificial intelligence methods retinopathy and their fields of application. We also presented the methods that we will use later in our work. The next part is devoted to the analysis and design of our application, which implements an application that is used to help with the diagnosis of illnesses.

## 1. Introduction

As we have seen in the previous chapter, there are many methods of the early diagnosis of retinopathy diabetes systems. So, automatic detection systems were introduced aiming to facilitate the identification process, making it available globally in a time and cost-efficient manner. However, due to the limited reliable datasets and medical records for this particular eye disease, the obtained predictions ‘accuracies were relatively unsatisfying for eye specialists to rely on them as diagnostic systems.

Thus, we propose a combination of CNN and SVM methods in order to decrease their issues and increase the quality of their results.

## 2. Proposed methodology

In this study, we will develop a classification model using combined learning techniques (CNN and SVM) in order to attain an optimal classifier with higher precision and accuracy than existing models.

In this model, we introduce a promising solution for automated DR detection systems, as we will demonstrate the results of using several classification algorithms. As briefed in Figure 2.1, specific features fed into the ensemble framework. During which, the model will be trained using part of the chosen datasets. Several widely common classification algorithms will be employed to improve the system’s prediction accuracy, which are Convolutional Neural Network (CNN) to perform complex mathematical calculations for improving precision, and a Support Vector Machine (SVM) algorithm for generating predictions in an accurate, timesaving and storage efficient manner. In the final stage, the output of all algorithms will be merged by a Meta-classifier to produce the final prediction.

## 3. System Architecture

In this section, we’re presenting the architecture of the proposed system, including its different components involved in its functioning:

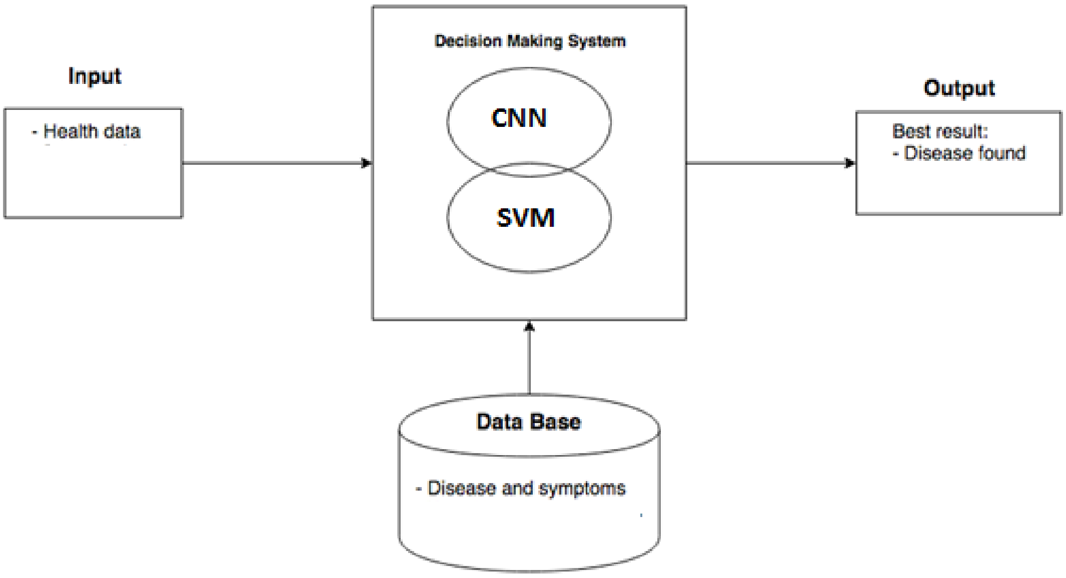



Figure 2.1. : System architecture

**Inputs:** this part includes all the user data that are related with the system domain and needs; data must be correct and meaningful according to system domain to ensure efficiency and getting the best results.

**Decision Engine Unit (DEU):** representing the main component of our system, containing the two combined methods, its role is to receive data, and send decision results.

**Database:** containing all needed data concerning system domain.

**Output:** represented by system results after input data processing.

## 4. General system functioning

The user enters the needed data to the system by the input part. The data entry process is done by a UI (User Interface) where he can input the data related to the system domain, after that the user data will be transmitted to the DEU, which is the part where the new decision-making method will be applied on user data, by connecting to the database and comparing similarities between them. After getting results, they will be transmitted to output part to be displayed to the user as best decisions.

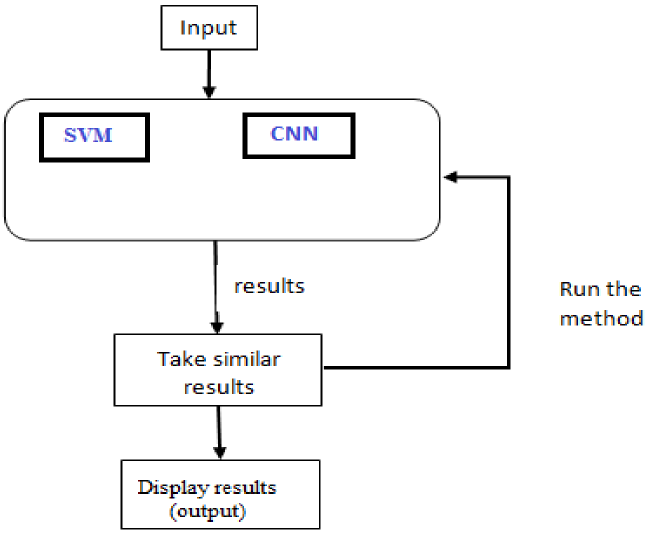



Figure 2.2 : General system functioning

#### 4.1. SVM Algorithm

Support Vector Machine" (SVM) is a supervised machine learning algorithm that can be used for both classification or regression challenges

**Algorithm:** WSVE $(S, D, k, \gamma, \nu, \mu, \sigma)$
**Input**: $S = \{\langle x_i, y_i \rangle\}_{i=1}^{m}$, $D$, $k$, $\gamma$, $\nu$, $\mu$, $\sigma$
**Output**: $h(\cdot)$

**begin**
  Select $J$ such that $\sum_{j \in J} D(j) \leq \sigma$, and it has minimum cardinality.
  Set $S^* = \{\langle x_j, y_j \rangle\}_J$.
  Set $D^* = D_J / \sum D_J$.
  $h(\cdot) \leftarrow$ MWSV $(S^*, D^*, k, \gamma, \nu, \mu)$.
**end**
Output the hypothesis $h(\cdot)$

**Figure 2.3: SVM algorithm**

#### 4.2.CNN Algorithm

CNN is mainly used in image analysis tasks like Image recognition, Object detection & Segmentation

1. This method can be implemented in simple consecutive steps: I
2. import TensorFlow.
3. Download and prepare the dataset.
4. Verify the data.

5. Create the convolutional base.
6. Add Dense layers on top.
7. Compile and train the model.
8. Evaluate the model.

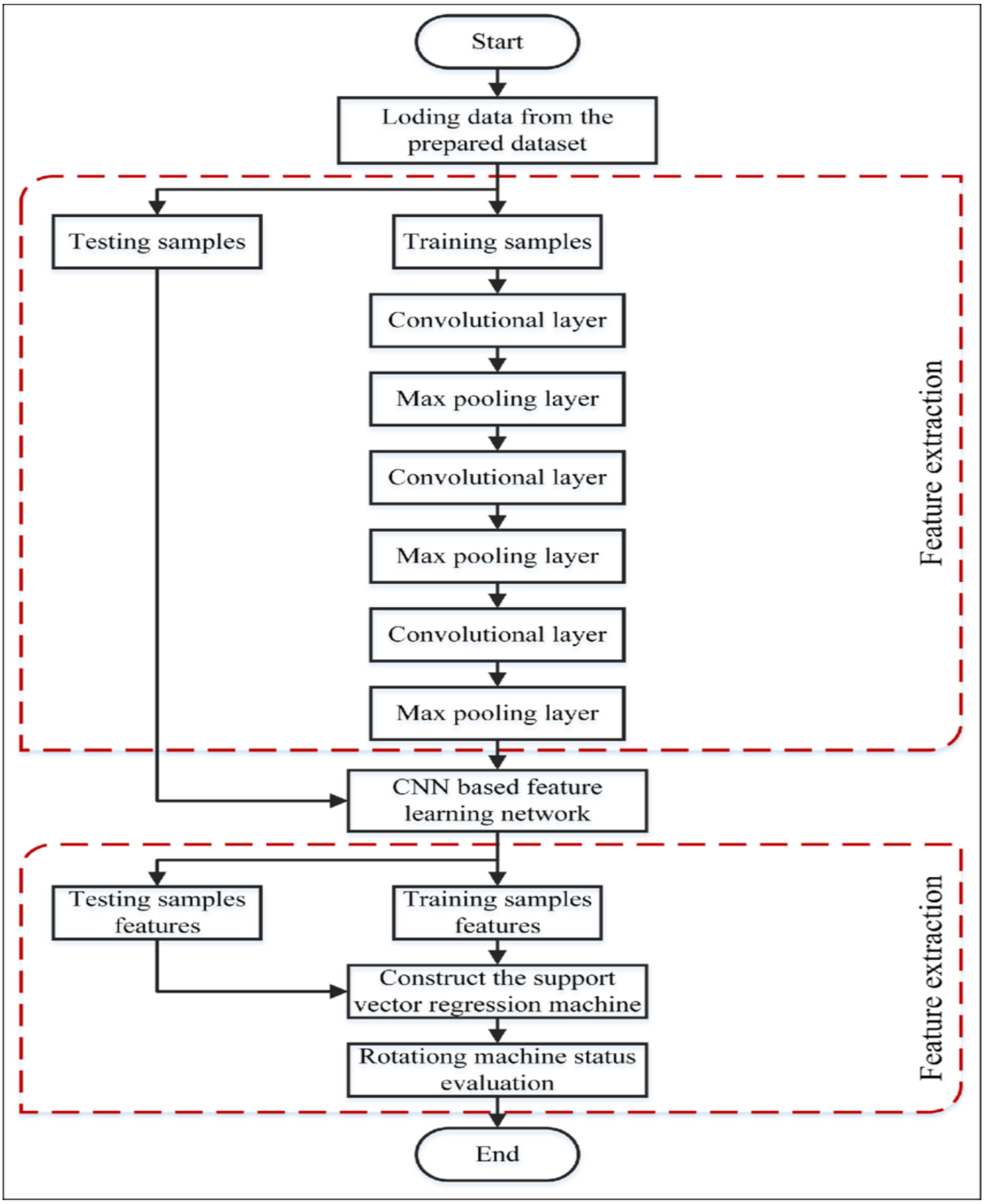



**Figure 2.4. CNN algorithm**

### 4.3. Hybrid method

This is the global method that uses the two previously mentioned methods.

```
** Input **
        L: input list
        DB: database
** Process **
    cnnResults = Cnn_method (L, DB);
    svmResults = Svm_method (L, DB);
    Result = cnnResults ∩ svmResults;
    If (result is not empty)
    {
        Display message "DR proliferative";
        Return result;
    } else if (result is empty AND (cnnResults is not empty OR svmResults is not empty)
        {
            Display message "DR Non-proliferative";
            Return result;
        } else  {
                Display message "No DR detection";
                Return result;
            }
** Output **
    Result
```

# 5. Concept Modeling

## 5.1. Definition

A conceptual model is the set of concepts within a system and the relationships among those concepts. A system conceptual model describes, using one diagram type or several diagram types the various aspects of the system. The conceptual model might include its requirements, behavior, structure, and properties. In addition, a system conceptual model is accompanied by a set of definitions for each concept [16]

### 5.2.Unified Modeling Language (UML)

#### i. Definition

Unified Modeling Language, UML for short, is the international standard notation for Object-Oriented Analysis and Design (OOAD). It has been defined by the Object Management Group (OMG) and has already become the de-facto standard for designing Object-Oriented Software Applications.

UML is a graphical language for visualizing, specifying, constructing, and documenting the artifacts of a software-intensive system. The UML gives you a standard way to write a system's blueprints, covering conceptual things, such as business processes and system functions, as well as concrete things, such as classes written in a specific programming language, database schemas, and reusable software components. [17]

#### ii. Benefits

- Models help us to visualize a system as it is or as we want it to be.
- Models permit us to specify the structure or behavior of a system.
- Furnish abstractions to manage complexity.
- Decrease development costs.
- Manage the risk of mistakes.
- Models give us a template that guides us in constructing a system.

#### iii. UML diagrams

UML 2.0 has thirteen types of diagrams representing as many separate views for represent particular concepts of the information system. They are divided into two major groups: [18]

- ❖ **Structural diagrams or static diagrams:** which contain:
  - o **Class diagram:** static structure representing the classes and interfaces of the systems as well as the different relationships between them.
  - o **Object diagram:** it is used to represent class instances (objects) used in the system.

- **Component diagram:** It allows to show the system components from a physical point of view.
- **Deployment diagram:** It shows the components on the hardware devices.
- **Package diagram:** provides a representation of a top-level graph of the organization of the application, and it helps to identify the links of generalization and dependency between packages.
- **Composite structure diagram:** provides a graphical representation of the classes, interfaces, and packages that make up a system, including ports and parties that describe their internal structures.

❖ **Behavioral diagrams or dynamic diagrams:**

- **Use case diagram:** It allows to identify the possibilities of interaction between the system and the actors (outside the system), i.e. all the functionalities what should the system provide
- **Activity diagram:** It describes the behavior of the system or its components as a flow or as a sequence of activities.
- **State machine diagram:** displays the possible states of the object and transitions that cause a state change
- **Sequence diagram:** sequential representation of the treatment process and the interactions between the elements of the system and / or its actors
- **Communication diagram:** provides a graphical representation of the interactions between the objects of a use case scenario, the execution of an operation, or an interaction between classes, with emphasis on the structure of the system
- **Interaction overview diagram:** It gives an overview of the interactions of the system. It is made with the same graphics as the activity diagram. Each element of the diagram can then be detailed using a sequence diagram or an activity diagram.
- **Timing diagram:** It is intended for the analysis and design of systems with real-time constraints. This is to describe the interactions between objects with strong temporal constraints. This diagram will not be studied in this course.

# 6. UML diagrams creation tool

Before starting to model our system, we will talk about the tool we used to draw the UML2 diagrams of our system, which is: **BOUML**.

### 6.1. Definition and features

BOUML is a Unified Modeling Language (UML) diagram designer. Programmed in C++ and Qt, it is multilingual, and supports code generation and code reverse engineering. The releases prior to version 4.23 are free software licensed under the GNU General Public License (GPL). BOUML 5 up to 6.12 is proprietary software. BOUML 7 and later is free software. It has these main features:

- it runs under Linux, Mac OS X and Windows thanks to Qt.
- it allows to program simultaneously in C++, Java, php, Python, IDL and MySQL.
- thanks to a full access to the generated forms, you are the master and you decide what must be generated.
- it is extensible, and the external tools (I name them plug-outs because they are executed outside BOUML) may be developed in C++ or Java, using BOUML for their definition as any other program.
- it is very fast and doesn't require much memory to manage several thousands of classes. [19]

| | |
|---|---|
| Developer(s) | Bruno Pagès |
| Stable release | 7.5 / April 16, 2018; 42 days ago |
| Written in | C++ |
| Operating system | Cross-platform |
| Available in | Multilingual |
| Type | Unified Modeling Language |
| License | Proprietary starting from v5.0 up to v6.12, free of use from v7.0 |
| Website | www.bouml.fr |

Figure 2.5. BOUML general information’s

# 7. Application Specification

### 7.1 Context and problem definition

Our application must allow the user to get diagnosed based on the symptoms that he gives to the system. The user has the choice between manually entering his symptoms or choosing from the suggestions while offering at the same time a simple user interface that is easy to use and understand.

### 7.2 Application objective

The purpose of our application is to give a correct retinopathy diagnosis to the user.

### 7.3 System actors

The functionality of the system requires the interactions of two actors:

- ❖ **The administrator:** it is the person in charge of the illnesses and symptoms database. He allows the users of the application to get their diagnosis.
- ❖ **The user:** it is a person who wants to get a diagnosis.

# 8. Requirement specification

In this part, we will define the different functional and non-functional needs of our solution.

### 8.1 Functional requirements

Functional requirements must meet the requirements of the future system in terms of functionality. They constitute a kind of promise or contract to the behavior of the generated system. As a result, the proposed solution must meet the following functional requirements:

- ✓ Allow the user to enter his symptoms.
- ✓ Allow the user to edit/delete his input.
- ✓ Show list of illnesses.
- ✓ Allow the administrator to set up the platform, maintain it and update the list of illnesses and their symptoms.

### 8.2 Non-functional requirements

Non-functional requirements can be considered as special functional requirements. Sometimes they are not attached to a particular use case, but they characterize the whole system (architecture, security, response time, etc.). The system must ensure the following operational requirements:

- **Material requirements:** The system must run in the same way on the different Android smartphones available on the market.
- **Deployment requirements:** The system must ensure the ease of setting up and deploying the application.
- **Performance requirements:** The system must respond quickly to the need of the user.
- **Availability / reliability requirements:** The system must:
  - Be available to users when requested, so 24/24 hours 7/7 days, except maintenance period and database update.
  - Operate properly at the user's request.
- **Robustness requirements:** The system must be able to adapt to changes in the environment.
- **Maintenance requirements:** The system must be easy to install and maintain.
- **Flexibility requirements**: The system must be flexible for future expansion.
- **Ergonomics of the interfaces:** The application must have a clear, intuitive and ergonomic interface.

# 9. Diagrams

### 9.1 Package diagram

Package diagram, a kind of structural diagram, shows the arrangement and organization of model elements in middle to large scale project. Package diagram can show both structure and dependencies between sub-systems or modules, showing different views of a system, for example, as multi-layered (aka multi-tiered) application - multi-layered application model. [20]

In our work, we see that our application may be divided into two parts (or packages) that can be observed separately:

- ✓ Decision making system.
- ✓ Data base management.

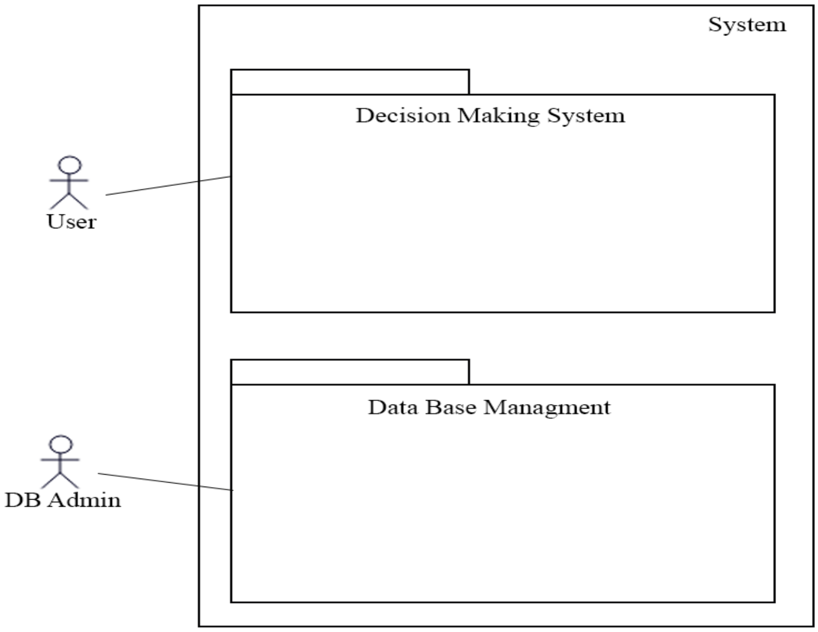



Figure2.6:  Package diagram

**9.2. Use case diagram**

Use case diagrams are usually referred to as behavior diagrams used to describe a set of actions (use cases) that some system or systems (subject) should or can perform in collaboration with one or more external users of the system (actors). Each use case should provide some observable and valuable result to the actors or other stakeholders of the system.

Use case diagrams are in fact twofold - they are both behavior diagrams, because they describe behavior of the system, and they are also structure diagrams - as a special case of class diagrams where classifiers are restricted to be either actors or use cases related to each other with associations.

This figure  illustrates the different use cases of the application for the user, while Figure clarifies the use cases for the database administrator.

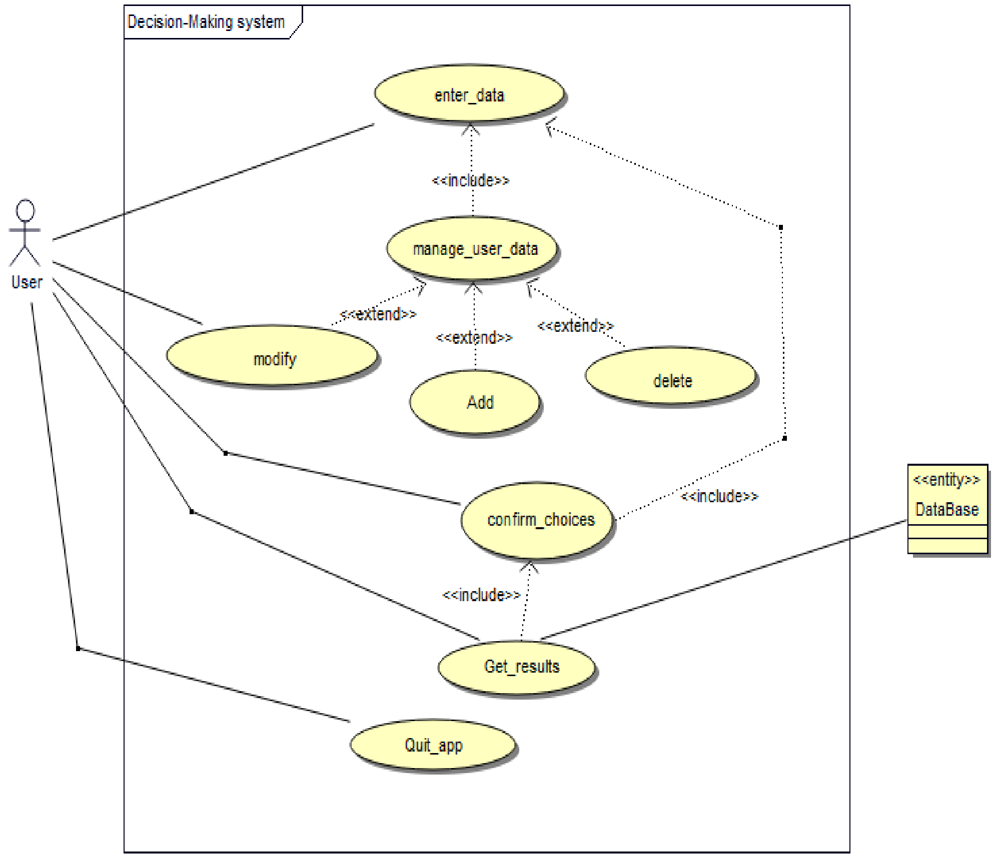



Figure 2.7: Use case diagram for the user

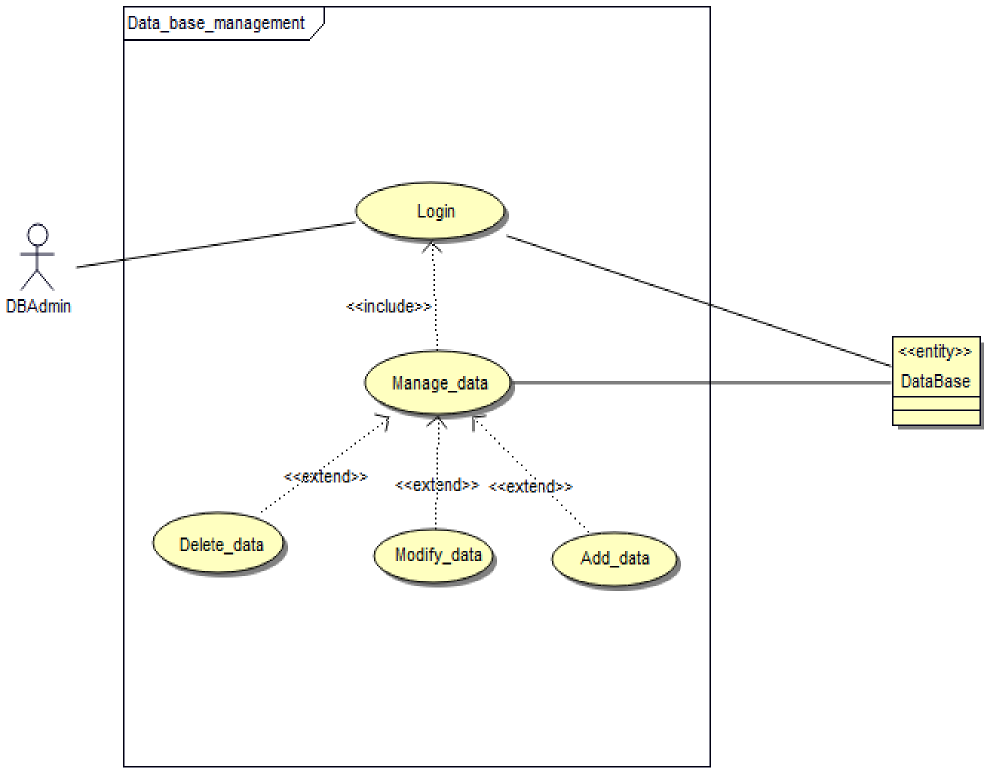



Figure 2.8: Use case diagram for the database admin

**Detailed use case diagram**

The description of a use case allows:

- ✓ Clarify the course of the functionality.
- ✓ Describe the chronology of the actions to be performed
- ✓ Indicate any constraints already known and which developers will have to take into account during the realization of the software. These constraints can be of diverse nature.

**Descriptive sheet of the use case "Enter Data":**

<table>
<tr><td colspan="2">SUMMARY</td></tr>
<tr><td>Title</td><td>Enter data</td></tr>
<tr><td>Goal</td><td>Enter symptoms to the system</td></tr>
<tr><td>Résumé</td><td>This use case allows the user to enter his symptoms to the system.</td></tr>
<tr><td>Actor</td><td>User</td></tr>
<tr><td colspan="2">DESCRIPTION OF THE EVENTS</td></tr>
<tr><td>Pre-condition</td><td>Post condition</td></tr>
<tr><td>- Application is open.<br>- User is on the input UI.</td><td>- Symptom is added.</td></tr>
<tr><td colspan="2">Nominal scenario</td></tr>
<tr><td colspan="2">1. The user opens the application by clicking its icon.<br>2. The user navigates to the input page.<br>3. The user clicks on the input field.<br>4. The user enter his symptom.<br>5. The user clicks on the "Add" button.<br>6. The application's input list is updated with the user's input.</td></tr>
<tr><td colspan="2">Alternative sequence</td></tr>
<tr><td colspan="2">A1: The user doesn't type any text in the input field and he clicks on "Add"<br><br>Sequence A1 starts at point 6 from the nominal scenario.<br><br>o 6. The application's input list is not updated.<br>o 7. The application shows a message that says: "Invalid Text".</td></tr>
</table>

- **Descriptive sheet of the use case "Modify Data":**

| **SUMMARY** | | |
|---|---|---|
| **Title** | **Modify data** | |
| **Goal** | Changing the value of an existing text | |
| **Résumé** | This use case allows the modification of the value of an already entered text. | |
| **Actor** | User | |
| **DESCRIPTION OF THE EVENTS** | | |
| **Pre-condition** | | **Post condition** |
| - Input list is not empty. | | - Input list item has a new value. |
| **Nominal scenario** | | |
| 1. The user selects an item from the input list.<br>2. The application asks the user to type his new value.<br>3. The user types the new value and clicks on the "Save" button.<br>4. The application's input list item is updated with the new value. | | |
| **Alternative scenario** | | |
| A1: The user doesn't type any text in the input field and he clicks on "Save"<br><br>Sequence A1 starts at point 4 from the nominal scenario.<br><br>○ 4. The application's input list item is not updated.<br>○ 5. The application shows a message that says: "Invalid Text".<br><br>A2: The user enters the same value of the selected item and he clicks on "Save"<br><br>Sequence A2 starts at point 4 from the nominal scenario.<br><br>○ 4.The application's input list item is not updated.<br>○ 5. The application shows a message that says: "Type a new value please.". | | |

- **Descriptive sheet of the use case "Delete Data":**

| **SUMMARY** | |
|---|---|
| **Title** | **Delete data** |
| **Goal** | Remove an element from the input list |
| **Résumé** | This use case allows the user to delete an element from the input list |
| **Actor** | User |

| DESCRIPTION OF THE EVENTS | |
|---|---|
| **Pre-condition** | **Post condition** |
| - Application is running.<br>- User at the input UI.<br>- Successfully added at least 1 element | - Element removed |
| **Nominal scenario** | |
| 1. The user selects an element from the input list.<br>2. The application shows a confirmation UI.<br>3. The user accepts by clicking Yes.<br>4. The application deletes the element.<br>5. The application shows the new input list | |
| **Alternative scenario** | |
| A1: The user refuse to delete.<br><br>Sequence A1 starts at point 3 from the nominal scenario.<br><br>o 3. The user refuse by clicking No.<br>o 4. The application shows the old input list. | |

- **Descriptive sheet of the use case "Get results":**

| SUMMARY | |
|---|---|
| **Title** | **Get results** |
| **Goal** | Get the list of disease |
| **Résumé** | Acquire the list of disease based on the input list |
| **Actor** | User |
| **DESCRIPTION OF THE EVENTS** | |
| **Pre-condition** | **Post condition** |
| - Symptoms were added successfully<br>- Connected with the database | - Show the list of disease |
| **Nominal scenario** | |
| 1. The user clicks on the button to get his results.<br>2. The application requests the data from the database.<br>3. The application applies the algorithms on the data and the input list.<br>4. The application shows the list of disease. | |

| Alternative scenario |
|---|
| A1: The algorithms don't find a matching disease.<br><br>Sequence A1 starts at point 4 from the nominal scenario.<br><br>○ 4. The application show a message that says: "No results were found". |

- **Descriptive sheet of the use case "Quit app":**

| SUMMARY | |
|---|---|
| **Title** | **Quit app** |
| **Goal** | Close the application |
| **Résumé** | This use case allows the user to close the application |
| **Actor** | User |
| **DESCRIPTION OF THE EVENTS** | |
| **Pre-condition** | **Post condition** |
| - Application is opened.<br>- User is on the first page. | - Application is closed. |
| **Nominal scenario** | |
| 1. The user clicks on the back button.<br>2. The application asks the user to confirm if he wants to exit.<br>3. The user confirms by clicking Yes.<br>4. The system closes the application. | |
| **Alternative scenario** | |
| A1: The user refuse to exit.<br><br>Sequence A1 starts at point 3 from the nominal scenario.<br><br>○ 3. The user refuse by clicking No.<br>○ 4. The application stays open.<br><br>A2: The user is not on the first page.<br><br>Sequence A2 starts at point 2 from the nominal scenario.<br><br>○ 2. The application returns to the previous page. | |

- **Descriptive sheet of the use case "Login":**

| **SUMMARY** | |
|---|---|
| **Title** | **Login** |
| **Goal** | Connect to the database |
| **Résumé** | This use case allows the database admin to connect to the database |
| **Actor** | Database admin |
| **DESCRIPTION OF THE EVENTS** | |
| **Pre-condition** | **Post condition** |
| -------------- | - Admin is connected to the database |
| **Nominal scenario** | |
| 1. Admin opens database administration tool and press on Login.<br>2. Tool asks for username and password.<br>3. Admin types his username and password.<br>4. Tool verifies his username and password.<br>5. Tool connects to the database. | |
| **Alternative scenario** | |
| A1: username and/or password are incorrect.<br><br>Sequence A1 starts at point 4 from the nominal scenario.<br><br>○ 5. Tool shows an error and asks the admin to re-enter his username and password. | |

- **Descriptive sheet of the use case "Add data":**

| **SUMMARY** | |
|---|---|
| **Title** | **Add data** |
| **Goal** | Add data to the database |
| **Résumé** | This use case allows the admin to enter new data to the database |
| **Actor** | Database admin |

| DESCRIPTION OF THE EVENTS | |
|---|---|
| **Pre-condition** | **Post condition** |
| - Admin logged in to the database | - Data added |
| **Nominal scenario** | |
| 1. The admin clicks on add.<br>2. The admin enters the data he wants to add.<br>3. The system shows the new added data and asks for confirmation.<br>4. The admin confirms his addition.<br>5. The system saves the new data. | |
| **Alternative scenario** | |
| A1: admin cancels the addition.<br><br>Sequence A1 starts at point 4 from the nominal scenario.<br><br>○ 4. The admin cancels the addition.<br>○ 5. The systems exits addition mod. | |

- **Descriptive sheet of the use case "Modify data":**

| SUMMARY | |
|---|---|
| **Title** | **Modify data** |
| **Goal** | Modify data base data |
| **Résumé** | This use case allows the database admin to change an already existing data |
| **Actor** | Database admin |

| DESCRIPTION OF THE EVENTS | |
|---|---|
| **Pre-condition** | **Post condition** |
| - Admin is logged in to the database<br>- Database is not empty | - Data is changed |
| **Nominal scenario** | |
| 1. The admin chooses which data he wants to modify.<br>2. The admin clicks on Modify.<br>3. The admin enters the new value.<br>4. The system shows the new data and asks for confirmation.<br>5. The admin confirms his modification.<br>6. The system saves the new value. | |

| **Alternative scenario** |
|---|
| A1: admin cancels the modification.<br><br>Sequence A1 starts at point 5 from the nominal scenario.<br><br>o 5. The admin doesn't confirm the modification.<br>o 6. The system exits modification mod. |

- **Descriptive sheet of the use case "Delete data":**

| **SUMMARY** | |
|---|---|
| **Title** | **Delete data** |
| **Goal** | Delete data from database |
| **Résumé** | This use case allows the admin to delete an already existing data from the database |
| **Actor** | Database admin |
| **DESCRIPTION OF THE EVENTS** | |
| **Pre-condition** | **Post condition** |
| - Admin logged in.<br>- Data already exists. | - Data deleted |
| **Nominal scenario** | |
| 1. The admin selects which data he wants to delete and clicks on delete.<br>2. The system asks for confirmation.<br>3. The admin confirms.<br>4. The system deletes the data. | |
| **Alternative scenario** | |
| A1: admin cancels the deletion.<br><br>Sequence A1 starts at point 3 from the nominal scenario.<br><br>o 3. The admin cancels the deletion.<br>o 4. The systems exits deletion mod. | |

### 9.3.Class diagram

Class diagram is a static diagram. It represents the static view of an application. Class diagram is not only used for visualizing, describing, and documenting different aspects of a system but also for constructing executable code of the software application.

It describes the attributes and operations of a class and also the constraints imposed on the system. The class diagrams are widely used in the modeling of object oriented systems because they are the only UML diagrams, which can be mapped directly with object-oriented languages.

Class diagram shows a collection of classes, interfaces, associations, collaborations, and constraints. It is also known as a structural diagram. [21]

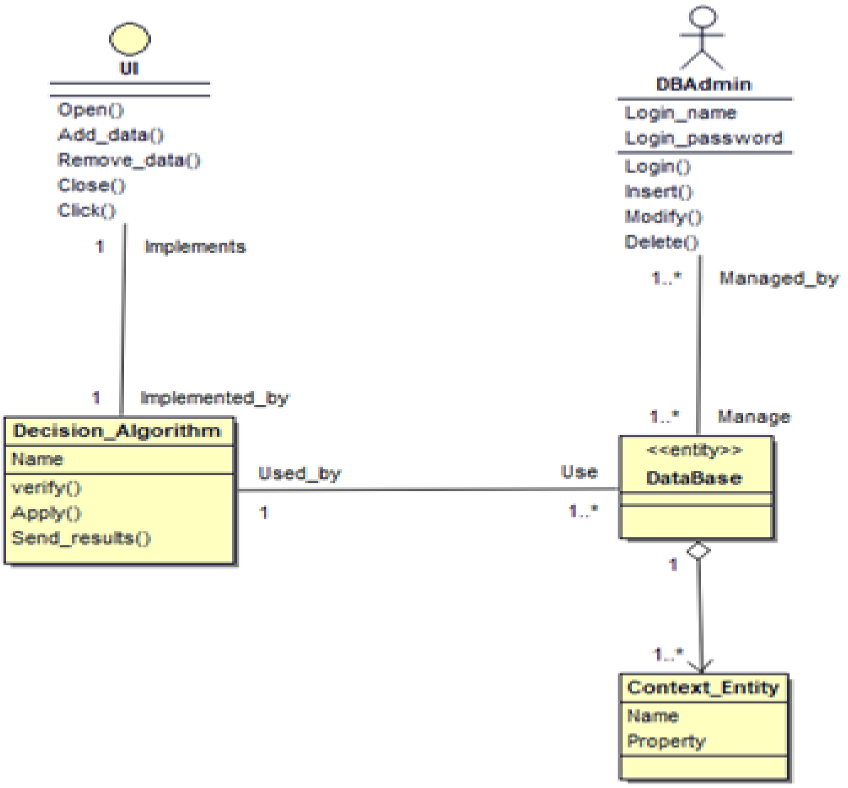



Figure2.9 : Class diagram

### 9.4. Sequence diagrams

UML Sequence Diagrams are interaction diagrams that detail how operations are carried out. They capture the interaction between objects in the context of a collaboration. Sequence Diagrams are time focus and they show the order of the interaction visually by using the vertical axis of the diagram to represent time what messages are sent and when.

Sequence Diagrams captures:

- the interaction that takes place in a collaboration that either realizes a use case or an operation (instance diagrams or generic diagrams).

- high-level interactions between user of the system and the system, between the system and other systems, or between subsystems (sometimes known as system sequence diagrams). [22]

**Sequence diagram for Enter data:**

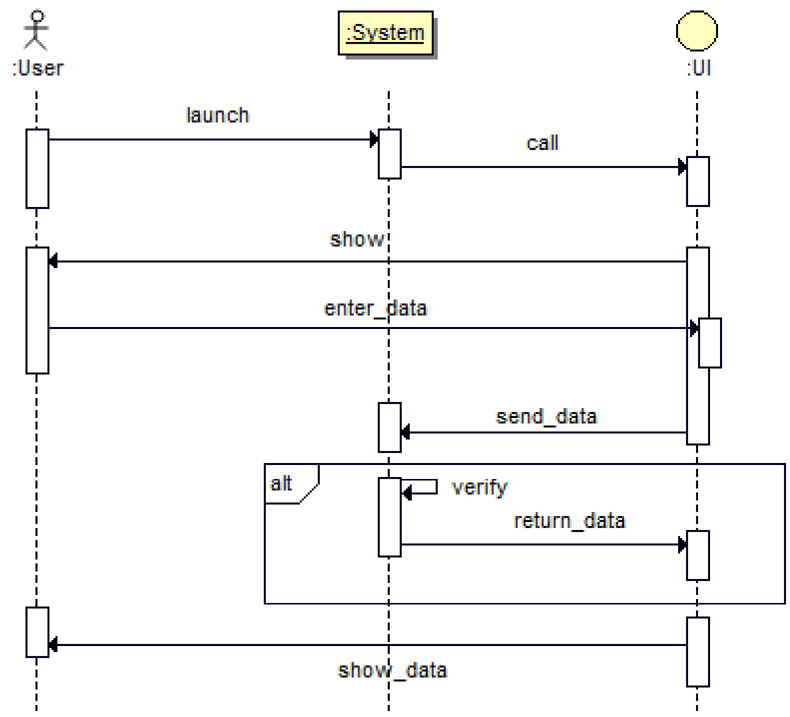



Figure 2.10 : Sequence diagram for Enter data

**Sequence diagram for Modify data:**

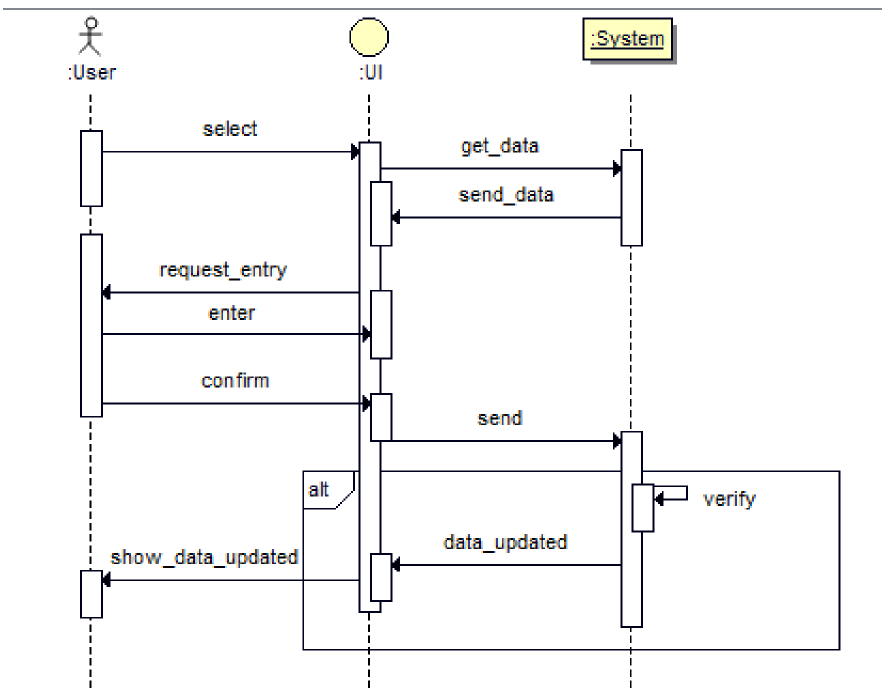



Figure 2.11 : Sequence diagram for Modify Data

## Sequence diagram for Add data:

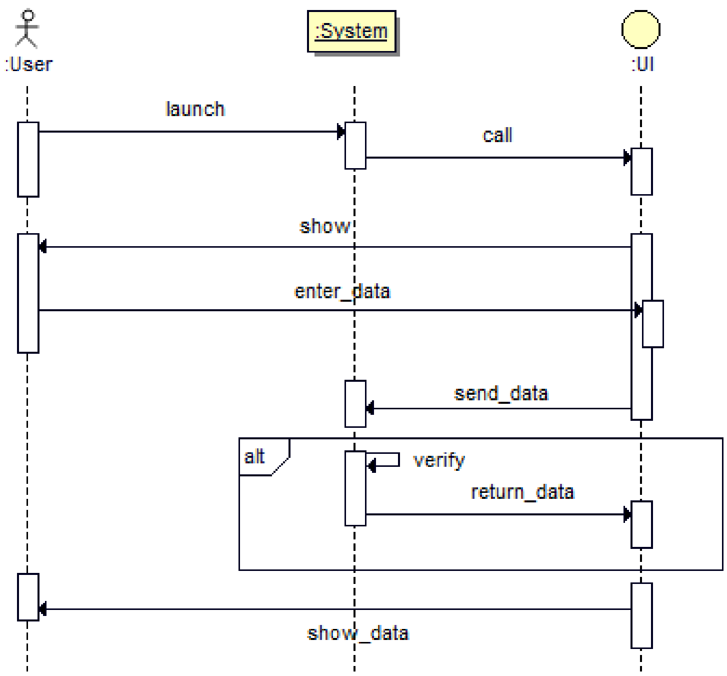



Figure 2.12: Sequence diagram for Add Data

## Sequence diagram for Delete data:

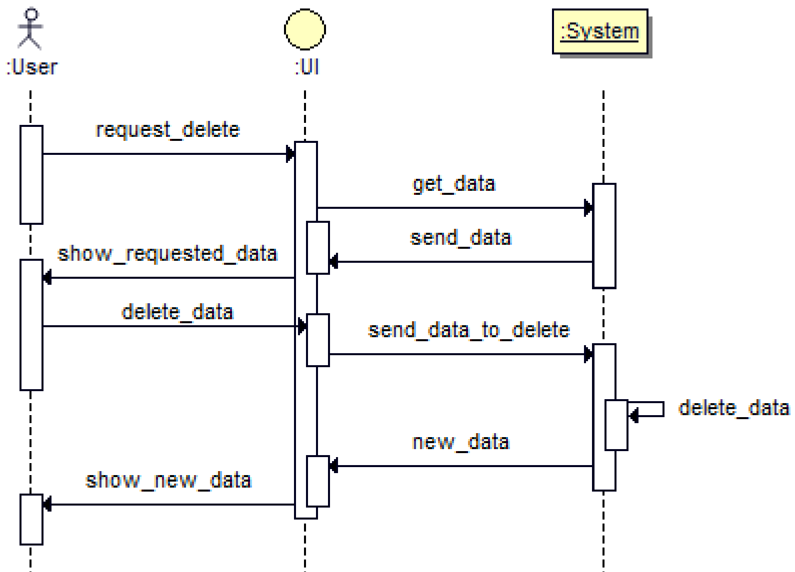



Figure 2.13: Sequence diagram for Delete Data

## Sequence diagram for Confirm choices:

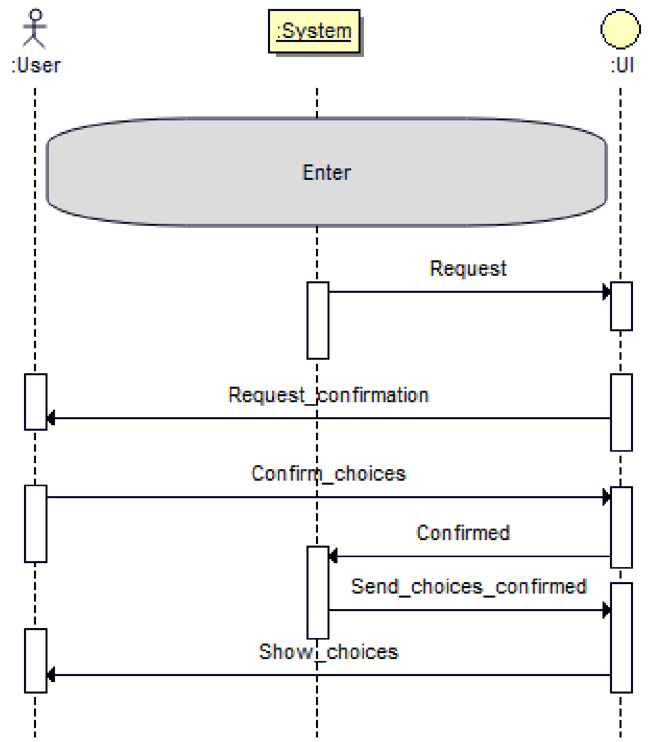



Figure 2.14 : Sequence diagram for Confirm Choices

## Sequence diagram for Get results:

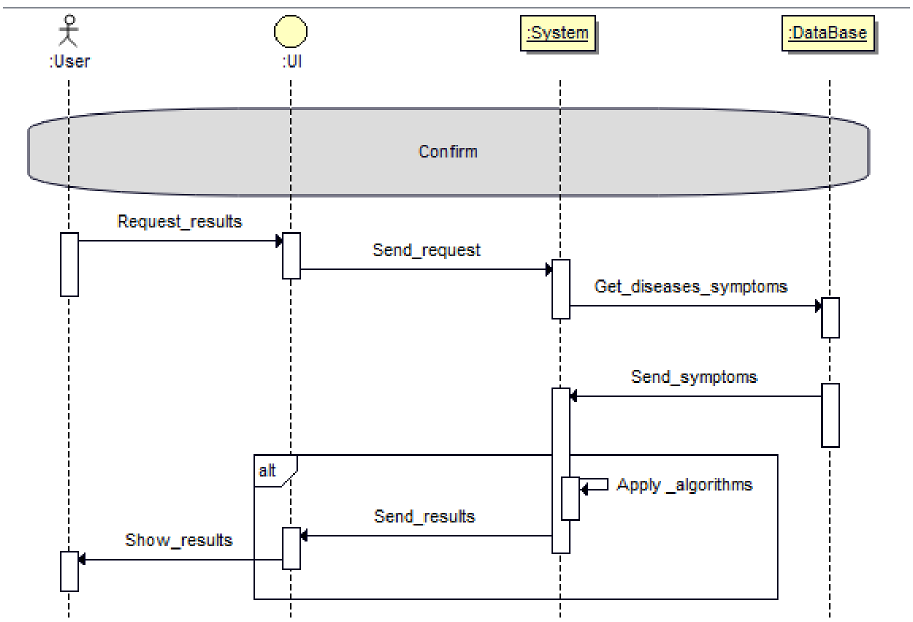



Figure 2.15 : Sequence diagram for Get Results

### Sequence diagram for Quit app:

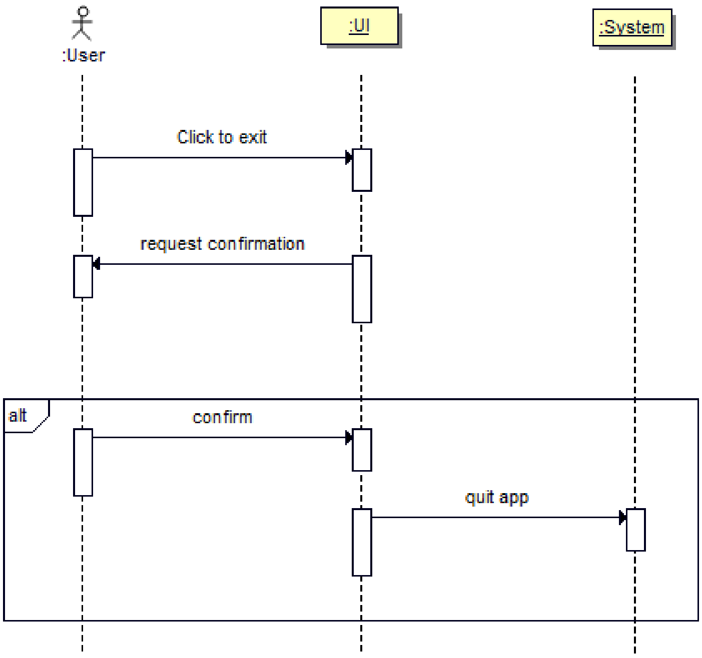



Figure 2.16 : Sequence diagram for Quit App

### Sequence diagram for login :

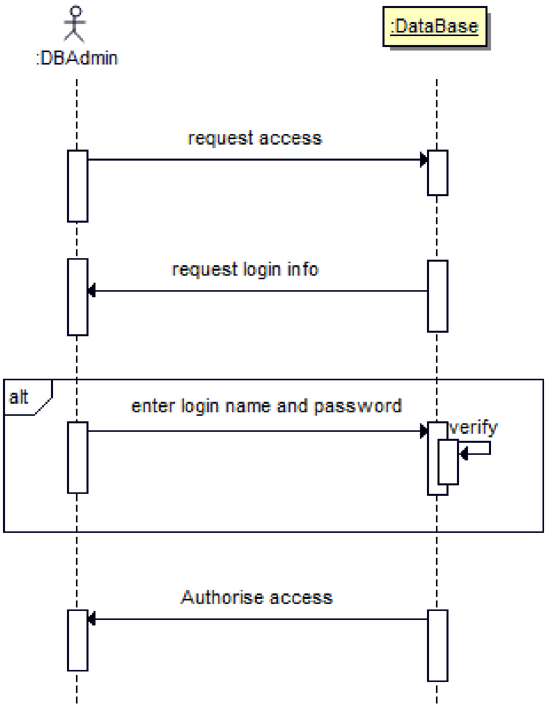



Figure 2.17 : Sequence diagram for Login

**Sequence diagram for Add data:**

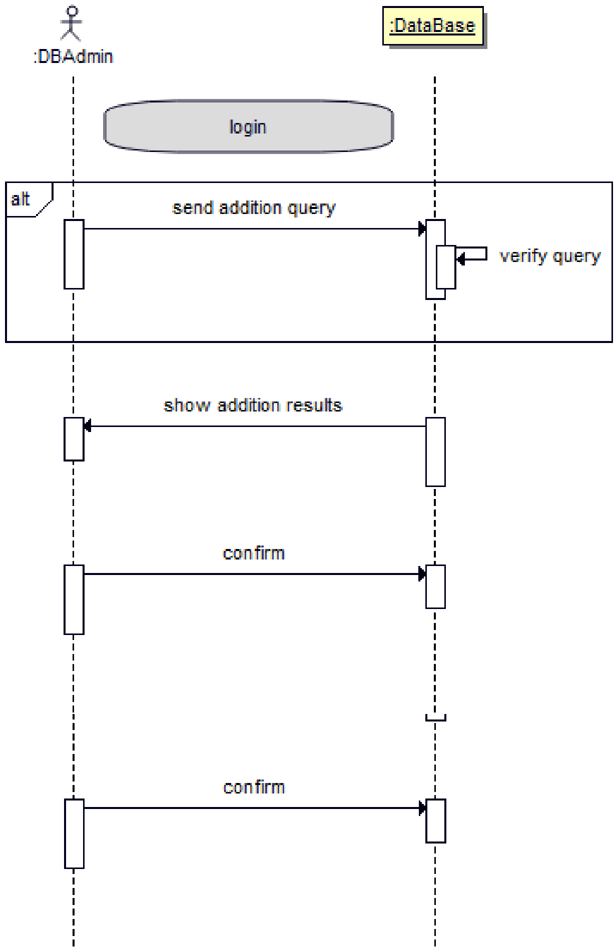



Figure 2.18: Sequence diagram for Add Data

- **Sequence diagram for Modify data :**

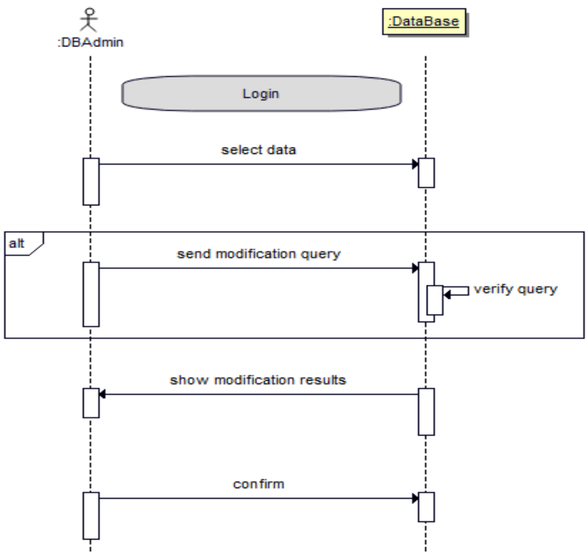



Figure 2 .19: sequence diagram for Modify Data

## 10. Conclusion

In this chapter, we have identified the goals of our application. This phase allowed us to develop the design patterns used to design our application. After that, we moved to detailed design to explain the classes of our application. Then, we designed some dynamic aspects of our application based on the sequence diagrams.

In the next chapter, we will go on to a description of the status of the project's implementation.

# Chapter 3: Implementation and Realization

## 1. Introduction

This chapter is the last step leading to the realization of our application.

The implementation stage consists of translating the result obtained during the conceptual stage into a program or computer software running on a machine using the tools of development adapted to the problem we're treating.

In what follows, we will describe the components of the work environment, as well as the implementation tools and we will give some examples of the interfaces that have been made in our application.

## 2. Environment of development

The realization of this project required the use of a number of tools and technologies listed below.

**Physical environment**

In order to realize our system, we used:

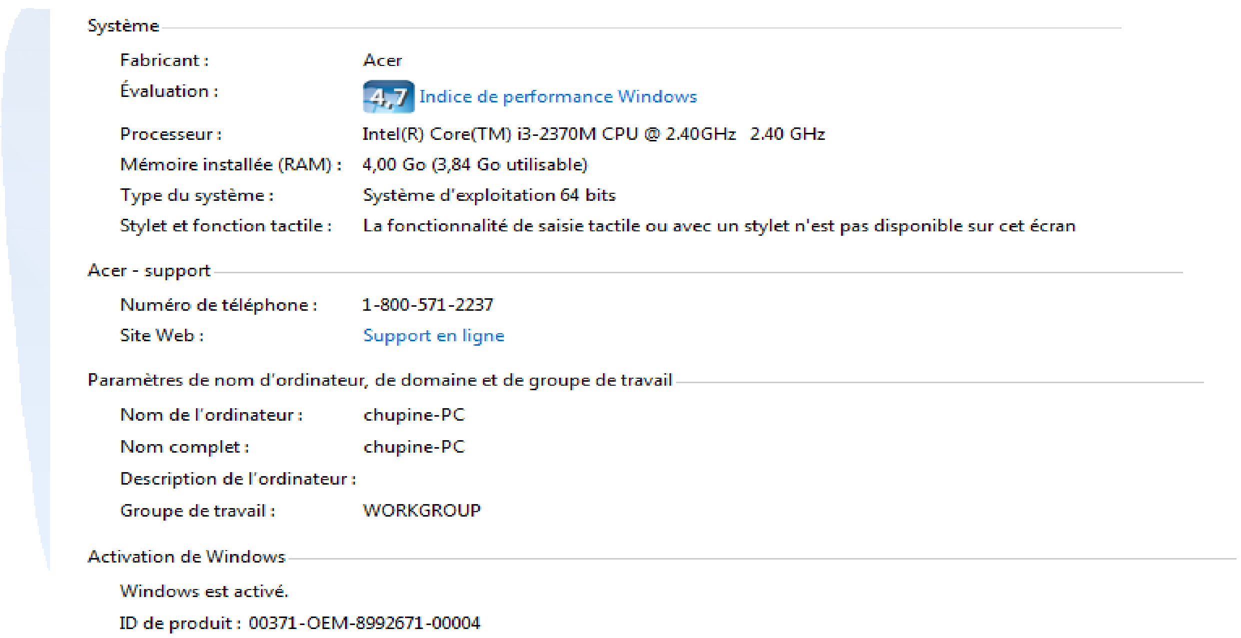



Figure 3.1: Materials Used

**Software environment**

- Desktop PC operation system: Windows 7.
- Programming language: Python.
- UML drawing tool: BOUML.

# 3. Technical choices

### 3.1 Jupyter note book penfer slow

Jupyter notebook is a well-known web tool for running live code. Apache Spark is a popular engine for data processing and Spark on Kubernetes is finally GA! In this tutorial, we will bring up a Jupyter notebook in Kubernetes and run a Spark application in client mode. We will also use a cool sparkmonitor widget for visualization. Additionally, our Spark application will read some data from AWS S3 that will simulate that locally with localstack S3.A flexible Gradle-based build system.

- All in one place:
- Easy to share:
- Easy to convert
- Language independent
- Easy to create kernel wrappers.
- Easy to customize:
- Extensions with custom magic commands:
- Stress-free Reproducible experiments:
- Effective teaching-cum-learning tool[23]

### 3.2 Python

Python is an interpreted, object-oriented, high-level programming language with dynamic semantics. Its high-level built in data structures, combined with dynamic typing and dynamic binding, make it very attractive for Rapid Application Development, as well as for use as a scripting or glue language to connect existing components together. Python's simple, easy to learn syntax emphasizes readability and therefore reduces the cost of program maintenance. Python supports modules and packages, which encourages program modularity and code reuse. The Python interpreter and the extensive standard library are available in source or binary form without charge for all major platforms, and can be freely distributed Nahit gitlab xml[24].

# 4. Presentation of the performed work

The following section contains some snippets of code with some application interfaces.

- **Code snippets**

The coming figures are parts of the application's source code that add precision to a specific classification model with dropout algorithm before fitting data.

```
Entrée [9]: from keras.applications.resnet import ResNet50, preprocess_input
from keras.preprocessing.image import ImageDataGenerator
from keras.layers import Dense, Activation, Flatten, Dropout
from keras.models import Sequential, Model
from tensorflow.keras.optimizers import SGD,Adam
from keras.callbacks import TensorBoard
import keras
import matplotlib.pyplot as plt

HEIGHT = 300
WIDTH = 300

BATCH_SIZE = 8
class_list = ["class_1", "class_2"]
FC_LAYERS = [1024, 512, 256]
dropout = 0.5
NUM_EPOCHS = 100
BATCH_SIZE = 8

def build_model(base_model, dropout, fc_layers, num_classes):
    for layer in base_model.layers:
        layer.trainable = False

    x = base_model.output
    x = Flatten()(x)
    for fc in fc_layers:
        print(fc)
        x = Dense(fc, activation='relu')(x)
        x = Dropout(dropout)(x)
    preditions = Dense(num_classes, activation='softmax')(x)
    finetune_model = Model(inputs = base_model.input, outputs = preditions)
    return finetune_model
```

Figure 3.2 : python code of neural nework

Display training data to drop unnecessary columns

Out[2]:

| | Filename | ExpCDR | Eye | Set | Positive |
|---|---|---|---|---|---|
| **0** | 001.jpg | 0.7097 | OD | A | 0 |
| **1** | 002.jpg | 0.6953 | OS | A | 0 |
| **2** | 003.jpg | 0.9629 | OS | A | 0 |
| **3** | 004.jpg | 0.7246 | OD | A | 0 |
| **4** | 005.jpg | 0.6138 | OS | A | 0 |

Figure 3.3 : Hider of train data base

Display an example of an image before un after processing brightness and saturation to get better data extraction

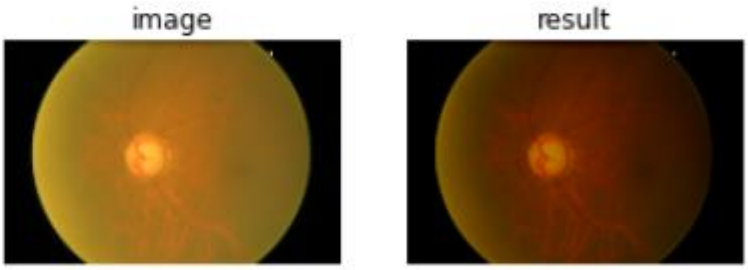



Figure 3.4 : Exemple of picture  before and after processing image

This code show the build Convolution neural network model function call

```
resnet50_model = build_model(base_model_1,
                                      dropout = dropout,
                                      fc_layers = FC_LAYERS,
                                      num_classes = len(class_list))
```

Figure 3.5:  CNN generaton code

This Figure shows the application's logo

Figure 3.6 :  Application icon

```python
def build_model(base_model, dropout, fc_layers, num_classes):
    for layer in base_model.layers:
        layer.trainable = False

    x = base_model.output
    x = Flatten()(x)
    for fc in fc_layers:
        print(fc)
        x = Dense(fc, activation='relu')(x)
        x = Dropout(dropout)(x)
    preditions = Dense(num_classes, activation='softmax')(x)
    finetune_model = Model(inputs = base_model.input, outputs = preditions)
    return finetune_model
```

Figure 3.7 : Fetting Cnn Model

```python
history = resnet50_model.fit_generator(generator = train_generator, epochs = NUM_EPOCHS, steps_per_epoch = 100,
                                       shuffle = True, validation_data = test_generator)
```

```
<ipython-input-10-a4889081ee2c>:1: UserWarning: `Model.fit_generator` is deprecated and will be removed in a future version. Pl
ease use `Model.fit`, which supports generators.
  history = resnet50_model.fit_generator(generator = train_generator, epochs = NUM_EPOCHS, steps_per_epoch = 100,
```

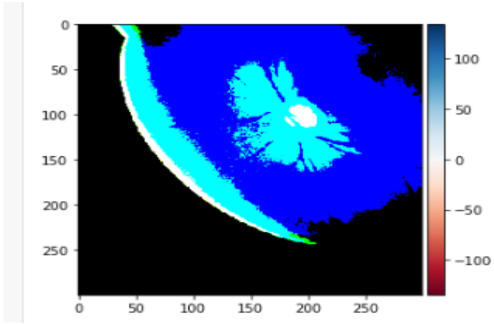
```
Epoch 1/100
 65/100 [==================>..........] - ETA: 2:36 - loss: 1.4155 - accuracy: 0.6538WARNING:tensorflow:Your input ran out of
data; interrupting training. Make sure that your dataset or generator can generate at least `steps_per_epoch * epochs` batches
(in this case, 10000 batches). You may need to use the repeat() function when building your dataset.
100/100 [==============================] - 424s 4s/step - loss: 1.4155 - accuracy: 0.6538 - val_loss: 0.6420 - val_accuracy: 0.
7385
```

Figure 3.8: Training result of each epoch

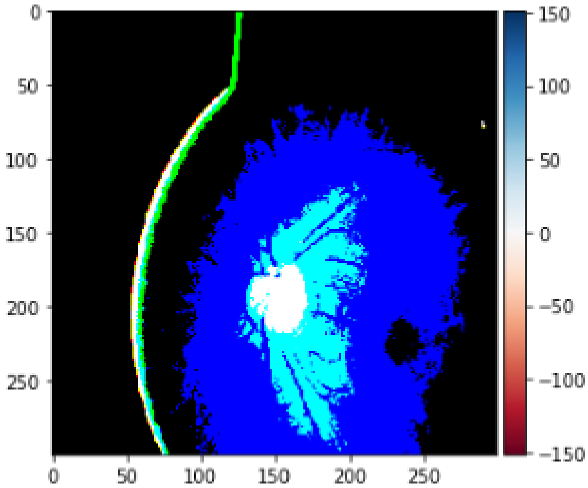
```
100/100 [==============================] - 424s 4s/step - loss: 1.4155 - accuracy: 0.6538 - val_loss: 0.6420 - val_accuracy: 0.
7385
```

Figure 3.9: Capture Moss and accuracy rent of the last step

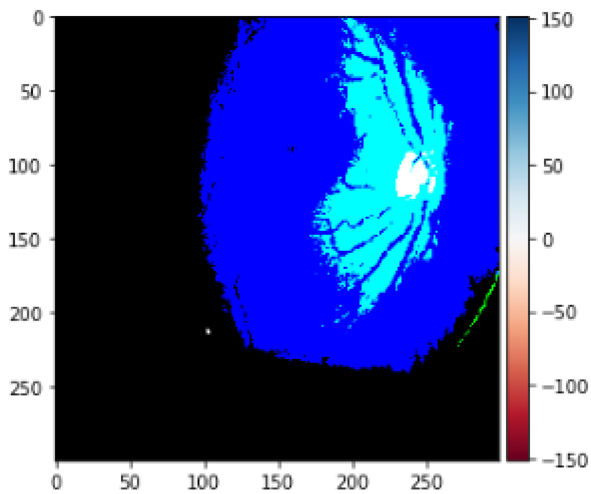
Clipping input data to the valid range for imshow with RGB data ([0..1] for floats or [0..255] for integers).



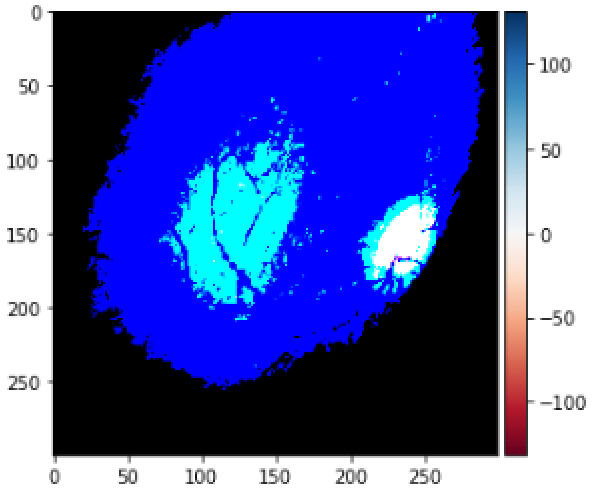

Clipping input data to the valid range for imshow with RGB data ([0..1] for floats or [0..255] for integers). [1. 0.]



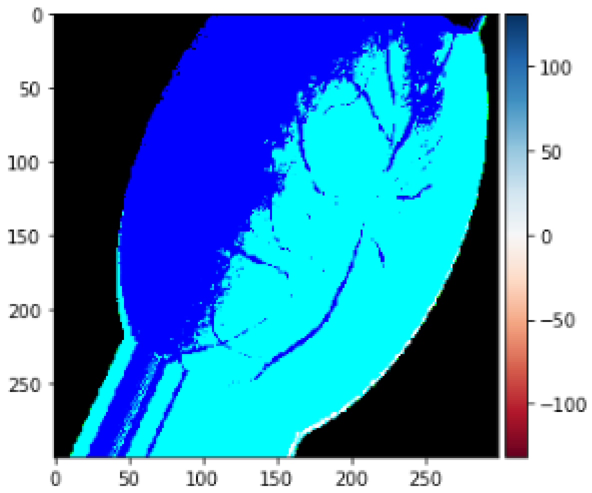

Clipping input data to the valid range for imshow with RGB data ([0..1] for floats or [0..255] for integers). [1. 0.]



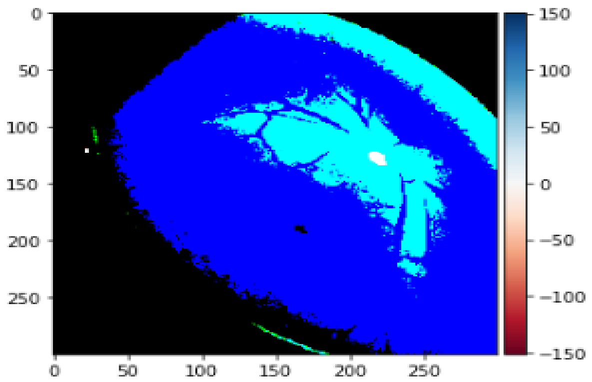

Clipping input data to the valid range for imshow with RGB data ([0..1] for floats or [0..255] for integers). [1. 0.]



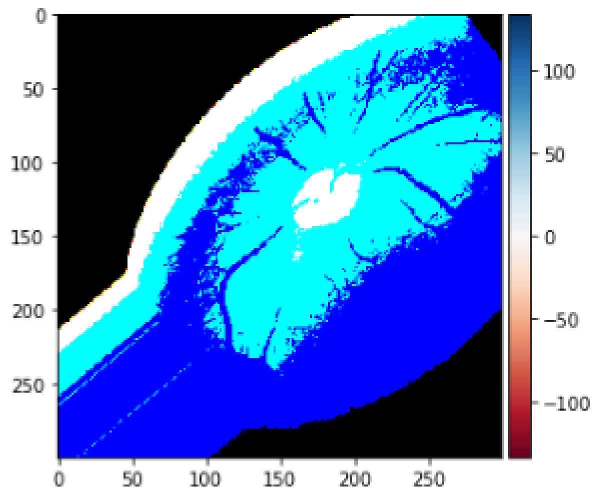

Clipping input data to the valid range for imshow with RGB data ([0..1] for floats or [0..255] for integers). [1. 0.]



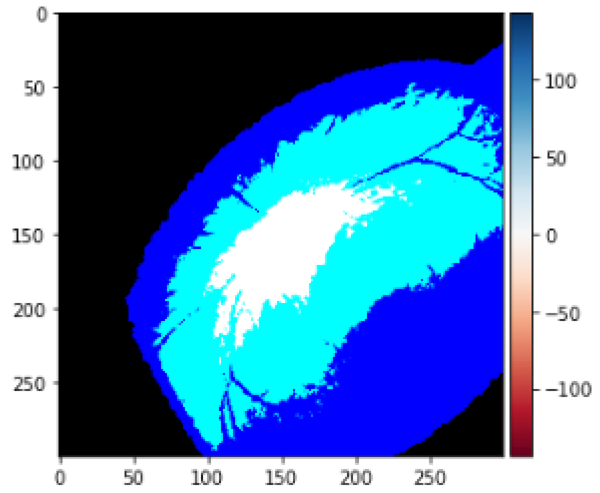

Clipping input data to the valid range for imshow with RGB data ([0..1] for floats or [0..255] for integers). [1. 0.]




Clipping input data to the valid range for imshow with RGB data ([0..1] for floats or [0..255] for integers). [1. 0.]




Clipping input data to the valid range for imshow with RGB data ([0..1] for floats or [0..255] for integers). [1. 0.]




**Batch image of our model**

## 5. Result and discussion:

- ✓ The classification process has passed throw 3 steps.
- ✓ The CNN single classifier got an accuracy value of 0.43;
- ✓ The SVM single classifier got an accuracy value of 0.49 but the hybridization of them together got an accuracy value of 0.74 which is much better result.
- ✓ 3 levels of classification (DR detection, No DR, DR proliferative)

## Conclusion

In this last chapter, we tried to present the essential approaches related to the implementation of our application.

To facilitate the understanding of our application, we have also presented the tools, the platform and the language used for the development of this mobile application, as we gave examples of the user interfaces and the source code to our application.

# General Conclusion

Diabetic retinopathy (DR) is a chronic disease of the retina, the number of patients with this pathology is increasing every year, therefore, screening for DR is currently a major problem.

Our work falls within the framework of diagnostic aid for the analysis of images of the fundus remotely using tools and techniques of artificial intelligence, and therefore reducing the number of patients who must be examined by the ophthalmologists. In addition, improve the quality of care offered to patients by maximizing the number of diabetics examined per year and reducing patient waiting times. Our application has been divided into two parts. This end-of-study project allowed us to deepen our theoretical knowledge, acquired throughout our training, through the practice of new information and communication technologies. This experience allowed us to master python development tools, namely the jupyter, whose development and integration of these methods did not require was not an easy task for us, but we did not hesitate to participate, despite the fact that there are few references. It also allowed us to discover how the connection of an application with a remote server takes place as well as the use of the python language to manage the communication of data between two heterogeneous. It is a very enriching experience in all areas.

Finally, the application we have developed could be enriched by other advanced features such as the integration of a direct communication system between the ophthalmologist and the patient; also the acquisition of retinal images requires great precision, we propose the use of a mobile ophthalmoscope to have precise, reliable and effective results.

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