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Thème

Application Web pour détecter le cancer de la peau (mélanome) à l'aide de l'apprentissage automatique

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Abstract

Skin cancer is one of the most common cancers in the world especially melanoma, and it is fatal if not treated early, that is why its early diagnosis is considered to be the best treatment for it. And under the light of recent advancements in computational power and in the artificial intelligence field (especially its 2 subdomains machine learning and deep learning) C.A.D (computer aided diagnosis) is considered to be one of the best ways for early skin cancer diagnosis. That is why we are going to make a diagnosis system for melanoma skin cancer, which has the most fatality rates between the 2 most common types of skin cancer. Our system is going to be a web-based platform, easy to use and, accessible to everyone through the Internet.

الملخص

يعد سرطان الجلد من أكثر أنواع السرطانات شيوعًا في العالم خاصة الميلانوما ، وهو قاتل إذا لم يتم علاجه مبكرًا ، ولهذا يعتبر التشخيص المبكر له هو أفضل علاج له. وفي ضوء التطورات الحديثة في القوة الحسابية وفي مجال الذكاء الاصطناعي (خاصةً المجالين الفرعيين للتعلم الآلي والتعلم العميق) ، يُعد C.A.D (التشخيص بمساعدة الكمبيوتر) أحد أفضل الطرق للتشخيص المبكر لسرطان الجلد. لهذا السبب سنقوم بعمل نظام تشخيص لسرطان الجلد الميلانيني ، والذي يحتوي على أكثر معدلات الوفيات بين النوعين الأكثر شيوعًا من سرطان الجلد. سيكون نظامنا عبارة عن نظام أساسي قائم على الويب ، وسهل الاستخدام ، ويمكن للجميع الوصول إليه عبر الإنترنت.

Resumé

Le cancer de la peau est l'un des cancers les plus répandus dans le monde, en particulier le mélanome, et il est mortel s'il n'est pas traité tôt, c'est pourquoi son diagnostic précoce est considéré comme le meilleur traitement. Et à la lumière des avancées récentes en matière de puissance de calcul et dans le domaine de l'intelligence artificielle (en particulier ses 2 sous-domaines d'apprentissage automatique et d'apprentissage profond), la C.A.D (diagnostic assisté par ordinateur) est considérée comme l'un des meilleurs moyens de diagnostic précoce du cancer de la peau. C'est pourquoi nous allons créer un système de diagnostic du cancer de la peau mélanome, qui a le taux de mortalité le plus élevé entre les 2 types de cancer de la peau les plus courants. Notre système sera une plate-forme Web, facile à utiliser et accessible à tous via Internet.

Keywords : Skin cancer - Melanoma - Machine learning - Classification - Diagnostic

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Chapter 1

General Introduction

In this article we are going to present our web-based diagnosis system for melanoma skin cancer, but before diving into the technical stuff we need to define the background first, so we don't get lost in medical/technical terms later on. That is why firstly in the general medical information chapter we defined and explained some medical and biological concepts we talked about skin anatomy, the background of cancers in general and ended it talking about skin cancer in particular, its definition, most widespread types, causes, risk factors and potential treatments with (early diagnosis + removal of tumor) being the best combination for treatment. Secondly in the general AI information chapter we explained and presented Artificial Intelligence concepts, we talked about its 2 sub categories machine learning and deep learning and their characteristics and ended it talking about Computer Vision because it was the most used branch of AI in the discussed methods, we mentioned its implementation in both machine learning and deep learning and its famous applications.

In the next chapter we talk about our chosen CNN architecture for this task, we talked about our proposed model in detail, dataset we have used to train it, the preprocessing issues and techniques we have used and finally, we presented the experimental results with the accuracy being 97%.

After that we dive in the technical stuff, where we explain the implementation process in detail, we presented our design and our application and the different software and hardware used to reach our final product.

Chapter 2

General Medecal Information

2.1 Skin

The skin is a complex organ [12], it is interactive, self renewing and represents the first and primary defense line against hostile environment, and it has several characteristics such as selective absorption, auto regeneration when injured, barrier to water loss, touch sensitivity ...etc. [13]. It represents the largest sensory organ (15% of total body weight and a total area of 1.86 m^2) [14], it has a highly adaptive structure that makes it vital for the survival of the human body, the balance between its static and dynamic properties makes it highly adaptive to the variations of the outer world [15].

2.1.1 Skin Anatomy

The skin is primarily composed of 3 main layers as shown in the figure 2.1, each layer has its unique properties and functions [14].

Epidermis The outermost layer which is constantly regenerating, contains the pigment melanin that determines the skin color, and it also represents a physical and biological barrier.

Dermis The middle layer, it supports the flexibility and gives strength to the epidermis, and it is mainly composed of connective tissue.

Hypodermis The last layer which is composed of subcutaneous fat which gives it its properties of being a main support of the overall structure of the skin and shock absorption.

2.1.2 Other entities also contained in the skin

Hair provides protection against minor trauma, and thermoregulation and filtering functions such as nasal hair and eyelashes

Sweat Glands it is found across the entire body, it provides lubrication, temperature regulation and salt and water balance.

their anatomies are shown in the figure 2.2

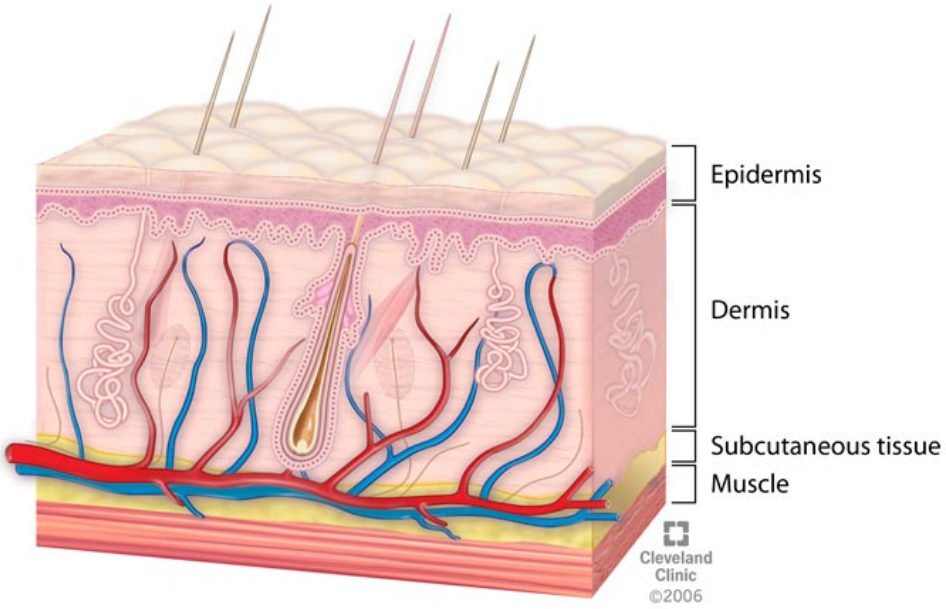

Figure 2.1: Skin Anatomy [1]

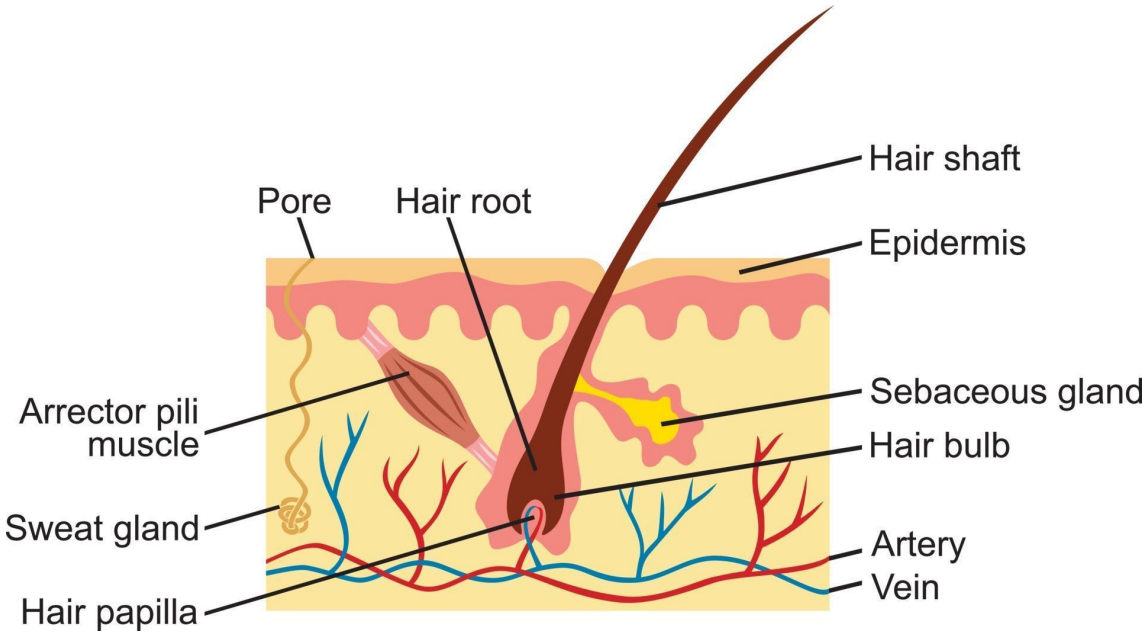

Figure 2.2: Hair and Sweat Glands Anatomy [2]

2.1.3 Functions of the Skin

The skin has 6 main functions that can be summarized as follows [14]

Protection
The skin is a direct interface between the internal organs and the environment, so it works as a protective barrier against harmful objects and pathogens (innate/adaptive immunity and ultraviolet light protection [13]) as shown in figure 2.3.

Thermostat
The skin works as a thermoregulator to keep the body at the optimal temperature of 37 C°, to achieve that is uses multiple strategies such as insensible perspiration, sweating ...etc.

Neural relay network
The skin contains a dense network of neural endings that works as receptors to various signals and provides sensations for touch, temperature and pain.

Expression and communication
A more social function is the ability for skin to enable individuals to display emotions. It acts as an indicator of one's physical state. Skin is an important component of the stress response as it acts as an immediate stress perceiver and as a target of stress responses. The skin also works as a social tool for interactions between human beings by indicating the physical state of the individual and by showing sign of stress.

Water storage
This skin works as a conservative barrier against water and body fluids' leakage as shown in figure 2.3.

Synthesis of vitamin D
The skin represents the main site of vitamin D production when exposed to the sun, it exists in the plasma membranes of basal and suprabasal keratinocytes in its inactive form then it is converted to previtamin D3 then to vitamin D in the liver and kidneys [13] as shown in figure 2.4.

2.2 Cancer

Cancer is an illness caused by the uncontrolled division and spreading of normal cells [16] unlike other diseases, cancer is caused by our own bodies and not by foreign entities, and it is one of the biggest causes of death among human beings nowadays (Table 2.1) and that is because of the ineffectiveness of traditional treatment methods such as hormones, surgery, radiation, and chemotherapy [17]. Their ineffectiveness is due to their side effects that lead the body to deteriorate more and more. But it is worth mentioning that there are some new methods and approaches being developed by researchers, a couple of those methods are the study of stem cells in relation to cancer cells and the study of the normal cells that the cancer cells came from which are called "Cancer Origin Cells", the latter approach proposes that we should study these origin cells because of their big similarities with cancer cells which will give us a roadmap to its diagnosis and therapy [18] .

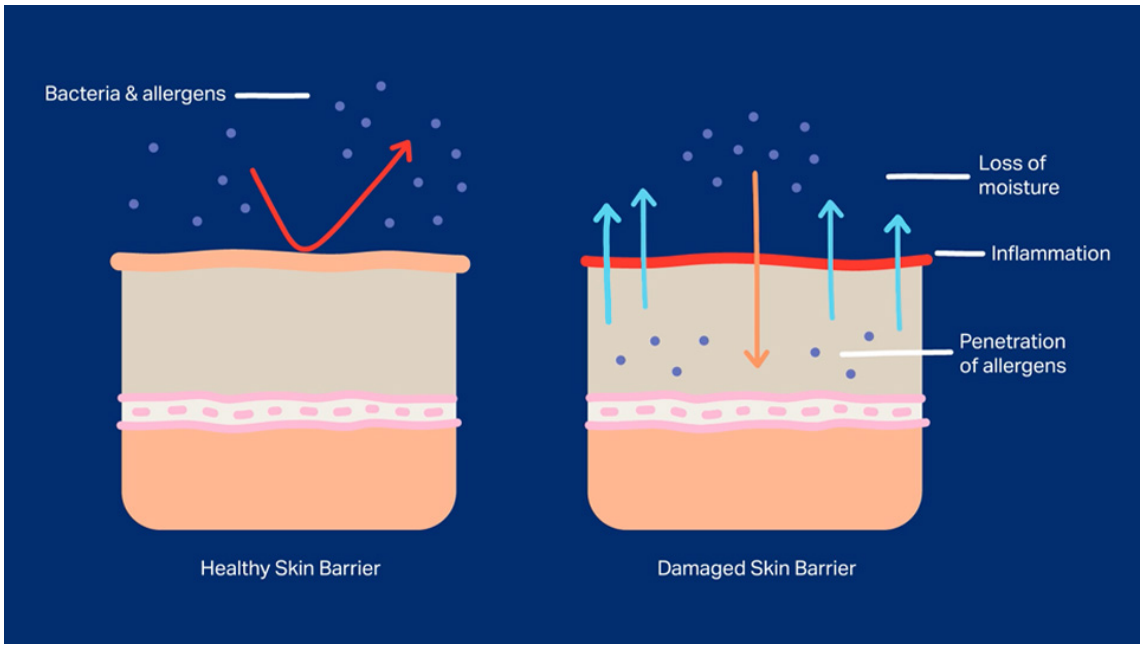

Figure 2.3: Protective/moisture Barrier Functions [3]

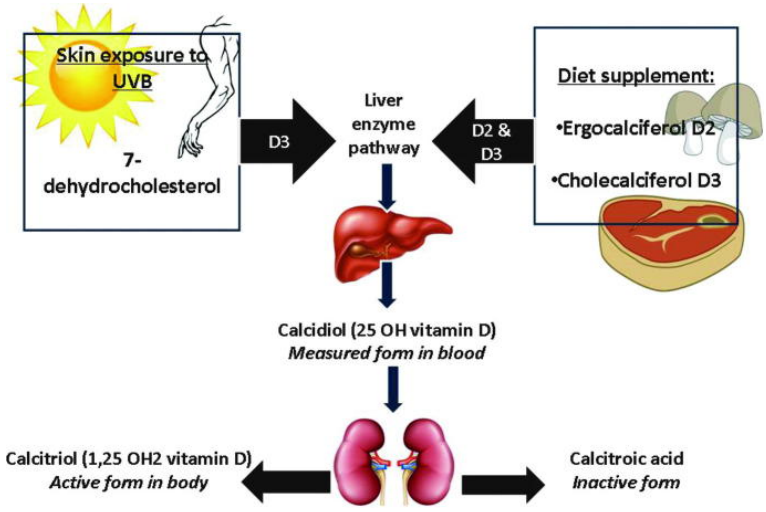

Figure 2.4: Hair and Sweat Glands Anatomy [4]

Deaths in 2020	nealry 10 million
Type	**New Cases** (millions) in 2020
Breast	2.26
Lung	2.21
Colon and Rectum	1.93
Prostate	1.41
Skin	1.20
Stomach	1.09

Table 2.1: Cancer Statistic [11]

2.2.1 Origin

One of the theories that discuss this is the "carcinogenesis multi-hit theory " which stipulates that for cancer to emerge there are some conditions (hits) that need to be satisfied these hits are produced by genetic mutations (figure 2.5) or rearrangements (figure 2.6) that occur over many years and the number of hits necessary is minimal ranging from 3 to 7 only [18]. But it is only fair to mention that there are some exceptions to the rule as there are some cancers caused by only one hit. And to go a step further these mutations can be caused by various elements in our environment such as chemicals in tobacco, ultraviolet rays...etc [16].

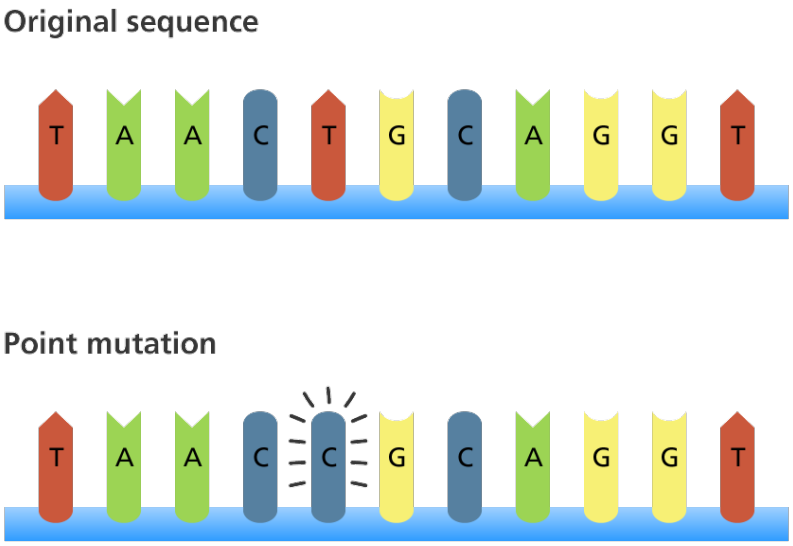

Figure 2.5: DNA Mutation [5]

2.2.2 Types

According to Fatality

Benign tumors

Are not very harmful because they do not spread to other organs and do not invade nearby tissue, and after removal, they usually don't grow back [16] as shown in figure 2.7.

Malignant tumors

Fatal if not treated, because they travel to distant places and form other tumors and invade nearby tissue [16] which makes it very hard to remove all its parts, as shown in figure 2.7.

According to Origin

Cancer is also categorized according to where it originated or its origin cells, in this category, there are over 100 types because of the different places it can appear (lung cancer, brain cancer ...)and the different origin cells that it can come from [16].

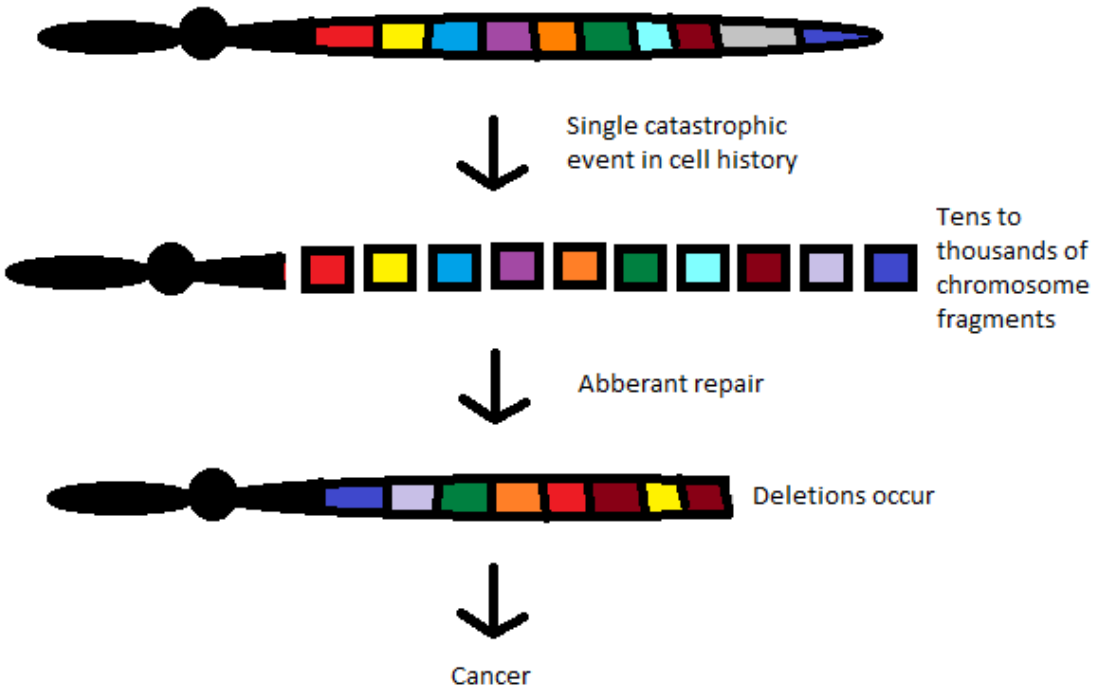

Figure 2.6: DNA Rearrangements [6]

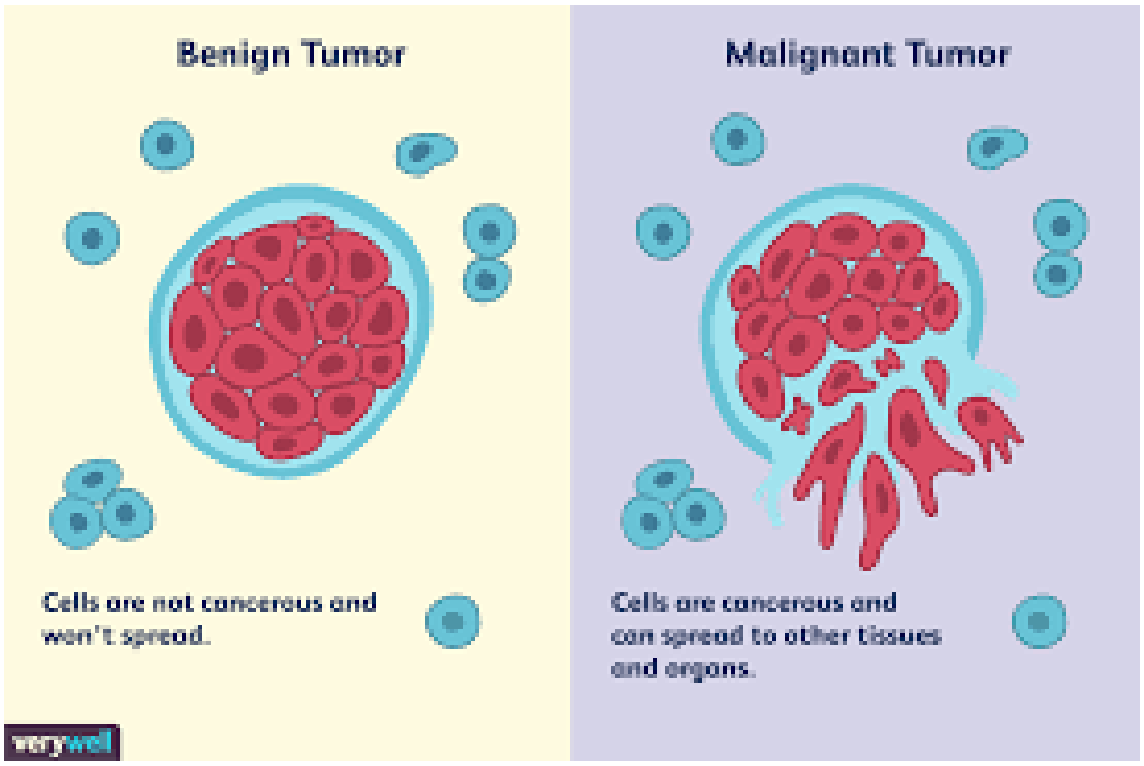

Figure 2.7: Benign and Malignant tumors [7]

Carcinoma
Most common type formed by epithelial cells.

Sarcoma
Forms in bone and soft tissue.

Leukemia
Forms in bone marrow, this type does form a tumor but travels in the blood.

Melanoma
Formed by melanocytes (cells that make melanin that gives the skin its color) ...etc.

2.3 Skin Cancer

Skin cancer is the abnormal growth of cells found in the epidermis (the outer layer of the skin) [19], it is one of the most common cancers in the world [20] and it falls under the category of a malignant tumor that is formed by fast multiplication of cells which is caused by mutations/damage in the DNA of those cells, the damage in their DNA is due to the exposure to ultraviolet rays [19] which can come from various sources but the most common are sunlight and tanning beds [19–21]. The most common types of skin cancer are basal cell carcinoma, squamous cell carcinoma , melanoma. The good news is that if it is discovered in an early stage or pre cancerous stage, it can be treated easily without leaving a scar.

2.3.1 Symptoms

Skin cancer can appear in any place on the body that is exposed to sunlight like : face, scalp, chest ...etc. But there are some cases where the cancer appeared in areas not always exposed to sunlight such as palm, soles, under the finger nails [21]. Skin cancer can happen to people of any skin color, but it is known that people with darker skins are less likely to have it because of the protection against ultraviolet rays provided by the melanin, which present in darker people in more quantities than pale people [21].

1. Basal cell carcinoma signs and symptoms Figure 2.8c
    - bump
    - flat brown scar
    - bleeding sore that heals and returns
2. Squamous cell carcinoma signs and symptoms Figure 2.8b
    - red nodule
    - flat lesion with crusted surface
3. Melanoma signs and symptoms Figure 2.8a
    - brownish spot
    - painful lesion that itches and burns
    - dark lesion

(a) Melanoma [22] (b) Squamous [23] (c) Basal [24]

Figure 2.8: 3 Most Common Types of Skin Cancer

2.3.2 Types

The 3 most common types are the following [19]

Basal cell carcinoma
The most common type with about 3.6 million new cases each year in the United States, if not treated early it can cause local destruction it can spread and in rare cases it is fatal.

Squamous cell carcinoma
The second most common type with about 1.8 million new cases in the United States each year, if not treated early it will spread, and it is in some cases fatal (15000 deaths/year in the United States).

Melanoma
One of the most common types, by 2022 it is estimated that, 197700 will appear in the United States, although it is treatable if detected early it is considered to be the most dangerous among common types because of its death rates (7650 deaths projected for the United States in 2022).

2.3.3 Causes

The most common and main cause of skin cancer is the exposure to ultraviolet [19–21] radiations that can primarily be found in sunlight and tanning beds, but there are some cases where the cancer appeared in areas not exposed to the sun like palms, soles, and under finger nails which indicates that other factors may contribute to the formation of skin cancer such as toxic substances, weak immune system, other types of radiation ...etc. [21]. The cells that the skin cancer originates from are squamous cells, basal cells and melanocytes. Squamous cells is just below the outer surface, basal cells is beneath squamous cells, and it produces new skin cells and melanocytes are the cells responsible for generating melanin which is the pigment responsible for the skin color. [21].

2.3.4 Risk Factors

Factors that may increase your chances of getting skin cancer are [21]

Fair skin
If you have less melanin which means your skin color is less dark than you are much

more likely to get skin cancer than a person with a darker skin because the melanin pigment is responsible for protecting the skin from ultraviolet effects.

History of sun burn
Having had sun burns before, either in childhood or adulthood, may increase your chances.

Exposure to the sun for long periods of time
Being exposed to the sun a lot or using tanning beds a lot is also one of the factors, a tan is your skin's injury response of ultraviolet rays.

High altitude climates
Living in higher places like mountains means that you are exposed to strong sunlight.

Moles
Some types of irregular moles -which are bigger than normal moles- can turn cancerous.

Precancerous skin lesions
There are some types of skin lesions -which are in themselves not cancerous - that are likely to turn cancerous, such as Bowen's disease and Actinic keratoses.

Family/Personal history of skin cancer

Weak immune system
Such as having HIV, AIDS or taking immunosuppressant drugs after an organ transplant...etc.

Exposure to radiation

Exposure to certain substances
Some harmful/unharmful substances can increase your chances, such as arsenic.

2.3.5 Prevention

As it is mentioned in [21, 25]

- avoid the sun at the middle of the day
- use sunscreen to protect against sunburn with an SPF (Sun Protection Factor) over 30
- protective clothing, especially when living in the desert
- avoid tanning beds
- always check your body for abnormalities and report them to your doctor
- see a dermatologist at lest once a year

2.3.6 Treatment

Before treatment, we need diagnosis first, there are two methods [26] to know that you might have skin cancer. The first method is by observing your skin frequently to see if there are some marks or abnormalities, after that you check in with a doctor who will preform further examinations which will bring us to the second method, skin biopsy -taking a part of the suspicious area of the skin and preforming some laboratory tests on it to have accurate results-. After confirming that you have a skin cancer, further tests will determine what stage is it at, which is often referred to with Roman numbers (**I-** means small and limited to the area where it started / **IV-** means advanced cancer that has spread to other parts of the body). Treatment methods may vary depending on the size, type and stage of the cancer [20] but the main way to treat cancer is to remove it completely especially if it is in early or precancerous stages otherwise if additional treatment is needed, the options are as mentioned in [26]:

- freezing with liquid nitrogen
- Mohs surgery, which is for difficult cases where the surrounding healthy skin can't be removed with cancerous cells (such as the nose area)
- Curettage and electrodesiccation to eliminate remaining cancerous cells
- Radiation therapy such as X-rays
- chemotherapy with substances that contain anti caner properties, such as lotions if the cancer is on the surface
- Photodynamic therapy, a combination of laser and chemicals
- Biological therapy using the body's own immune system

Chapter 3

Artificial Intelligence

3.1 Artificial Intelligence

3.1.1 Overview

After breaking the Enigma machine that was made by the Nazis for secure/encrypted communications in world war against the allies, Alan Turing once again changed the course of history by asking the following question "Can machines think?" in a paper he published in 1950 titled "Computing Machinery and Intelligence", this question is what gave rise to Artificial Intelligence, because all what artificial intelligence is trying to do is answer that question in the affirmative by trying to mimic human intelligence in machines [27] to do so Turing has put forward a test called "The Turing Test" which will be explained later. Because artificial intelligence is a concept that is so broad and general people don't always agree on a definition, but we found that the below definition is a good enough explanation.

3.1.2 Definition

"Artificial intelligence (AI) is a wide-ranging branch of computer science concerned with building smart machines capable of performing tasks that typically require human intelligence." [27]

3.1.3 Turing Test

It is basically a test put forward by the mathematician Alan Turing to determine whether a machine is intelligent or not, the test goes as follows, "If a machine can engage in a conversation with a human without being detected as a machine, it has demonstrated human intelligence." [28]

3.1.4 The 4 Types of Artificial Intelligence

Reactive Machines

It is one of the most basic form of artificial intelligence because as the title suggests it only reacts to its surrounding environment, and does not use a memory to try and learn from past experience, so it is purely reactive which means that this type of artificial intelligence can only be responsible for a very narrow and specialized

set of tasks, this narrowness can be looked at as a limitation but in fact it is what makes it special in being very trustworthy and error free. A famous example of this type would be the chess playing machine Deep Blue made by IBM in the 1990s which treats each move in the game as its own separate reality and doesn't rely on past moves [27].

Limited Memory

It is a type of artificial intelligence that relies on memory and automatic training, which means learning from experience to try to make optimized decisions/predictions, the learning steps in this type can be looked at as a feedback loop (generate data, learn, make model, make predictions, accept feedback), there are 3 major models that utilize this type [27]:

- Reinforcement learning: learning from trial and error.
- Long Short Term Memory (LSTM): uses past data to make predictions, the more recent the data the more weight it has on making predictions.
- Evolutionary Generative Adversarial Networks (E-GAN): this model grows constantly by putting 2 machines against each other, and they learn by bouncing information off of each other.

Theory of Mind

This is purely theoretical and technology is still not caught up to this, and it stipulates that machines would be able to understand how humans and animals think and feel and make decisions through self reflection [27].

Self-awareness

After Theory of Mind is established, this is the next step, where machines become self-aware and comprehensive of its own existence by obtaining human level intelligence and consciousness [27].

3.1.5 Artificial Intelligence Categories

Generally speaking, there are 2 categories of artificial intelligence [27]

Narrow artificial intelligence

Also known as "Weak artificial intelligence", it operates in a limited context and is often specialized in a single task such as : Google Search, Image Recognition, Self-Driving Cars...etc.

Artificial general intelligence

Also known as "Strong artificial intelligence", it is the kind of artificial intelligence we see in Science Fiction movies implemented in robots that have human level intelligence and that can apply its intelligence to solve any problem.

3.2 Machine Learning

3.2.1 Overview

Machine learning is a subfield of artificial intelligence that has a human like ability to learn from past experience through statistics and data, and it has helped us solve difficult world

problems ranging from medical problems to environmental issues, and the special thing about machine learning is its ability to solve these problems without being explicitly programmed to do so with the usual sequence of code lines that define normal (non-artificial intelligence) algorithms, but it relies on tacit knowledge (past experience) to try and find patterns and make predictions, humans use tacit knowledge all the time for example a person can't accurately explain how he preforms face recognition, but it is gained through the experience of observing that face numerous times in different angles and states [29].

3.2.2 Definition

"Machine learning is a subset of artificial intelligence that gives systems the ability to learn and optimize processes without having to be consistently programmed. Simply put, machine learning uses data, statistics and trial and error to "learn" a specific task without ever having to be specifically coded for the task." [29].

3.2.3 Types of Machine Learning Algorithms

There are 3 types [29]

Supervised Learning
: Supervised machine learning algorithms provide a mathematical model that can make the connection between inputs and outputs of the training data (pre-labeled data) in the most optimized way so that when it is provided with new data, it can make very accurate predictions. Regression and classification are the most popular supervised algorithms.

Unsupervised Learning
: Unsupervised algorithms take unlabeled input data and try to structure it in the form of clustering or grouping by taking into account commonalities or lack of commonalities.

Semi-Supervised Learning
: This type falls in the middle, it is given labeled and unlabeled data with unlabeled being the bigger percentage than the algorithm is going to cluster the unlabeled data through the structure of the labeled data which offers a huge optimization for both sides, because supervised learning requires a huge size of labeled data which is usually done by human beings which means that it takes a lot of time and is bound to human error, and Unsupervised learning algorithms takes a lot of time also figuring out the connections in the raw unlabeled data.

3.2.4 Examples and Applications

As mentioned in [29]

Financial Services
: This industry is using machine learning almost in every aspect, because of its ability to speed up the financial processes and preform tasks that used to take humans days or weeks in merely seconds. Such as handling millions of transactions, recommending personal offers ... etc.

Healthcare

This industry is also relying a lot on machine learning because of its ability to discover new treatments and detect and predict diseases, a medical professional equipped with machine learning is far more proficient because he can access a patient's relevant medical history in blink of an eye rather than digging through files or contacting other departments in the hospital. Machine learning is predicted to save the medical field billions of dollars annually.

Social Media

This industry usually uses machine learning for 2 main reasons: strengthening the feel of connection between people and eliminating bad actors, it does the former by providing individualized recommendations to friends, pages, and communities based on a user's preference or activity history, and for the latter it tries to prevent fake news before it becomes a thing, block malicious users and scams when detecting abnormalities.

...etc

3.3 Deep Learning

3.3.1 Overview

Yet again another subfield with great capabilities, although it seems to be a new concept, but it actually isn't as our professor Rahmoun Abdellatif once mentioned in a lecture talking about deep learning and neural networks, he said that the theoretical part was established a long time ago (1950's) but people back then didn't have the computational power to implement it, so it took quite some time for people to develop the necessary computational power to take on artificial neural networks and one of the scientists who made neural networks cool again is Geoffrey Hinton by demonstrating that a few of them could be trained using backpropagation for better shape recognition and word prediction and by 2012 deep learning is basically used everywhere [30].

3.3.2 Definition

"Deep learning (sometimes known as deep structured learning) is a subset of machine learning, where machines employ artificial neural networks to process information. Inspired by biological nodes in the human body, deep learning helps computers to quickly recognize and process images and speech. Computers then "learn" what these images or sounds represent and build an enormous database of stored knowledge for future tasks. In essence, deep learning enables computers to do what humans do naturally- learn by immersion and example." [30]

3.3.3 What Is Next?

Although deep learning has brought us many accomplishments, and it can be applied in various domains and when it is done right it can preform a certain task with super-human level but some scientists and researchers say it is only a small step in acquiring actual intelligent machines because it lacks the concept of abstract ideas and knowledge such

as: what objects are?, chat they are for?, how to use them?...etc. And also the problem of "data" because deep learning requires a huge amount of pre labeled data to be trained which is not always available and public datasets won't cut it [30].

And there are a lot of new concepts that are presenting promising results like "deep reinforcement learning" a combination of deep learning and reinforcement learning, and we can see this implemented in a software called AlphaGo and AlphaGo Zero, another research paper suggested "Reward learning from human preferences and demonstrations" which basically means machines learn from observing humans play games which they say it works better than trial-and-error systems [30].

other ideas that are worth mentioning [30]

ONE-SHOT LEARNING and NAS (neural architecture search)
One-shot learning means we need far fewer data to learn, and NAS means an algorithm finds the best neural network architecture to solve a problem, this combination is very promising.

GANS (Generative Adversarial Networks)
A competition for deep learning which puts 2 networks against each other (a generator and a discriminator) you can think of it as a counterfeiter and a cop.

AUTOML
Learn-to-learn, which basically means machine learning algorithms do the hard work of finding the design of the network and all we need to provide is data.

3.4 Ai vs Machine Learning vs Deep Learning

After all what we have talked about it is obvious that the relationship between the three is an inclusion relationship, deep learning is a subset of machine learning which is a subset of artificial intelligence as shown in Figure 3.1 .

3.5 Computer Vision

3.5.1 overview

Yet another subfield of artificial intelligence which is used to train machines to see, and by see we mean process analyze and extract useful information from images/videos just like us human beings, although our vision is far more advanced in many aspects because our brains were trained since birth to see, analyze objects, understand the distance and relationship between objects, attribute abstract information to objects...etc. But it is safe to say that machines can surpass our vision in certain specialized tasks because of their ability to process thousands of images/frames in a short period of time due to the constant increase in computational power especially (graphical processing). Computer vision is used in a wide variety of industries, and its market is estimated to reach 48.6 billion USD by 2022 [31].

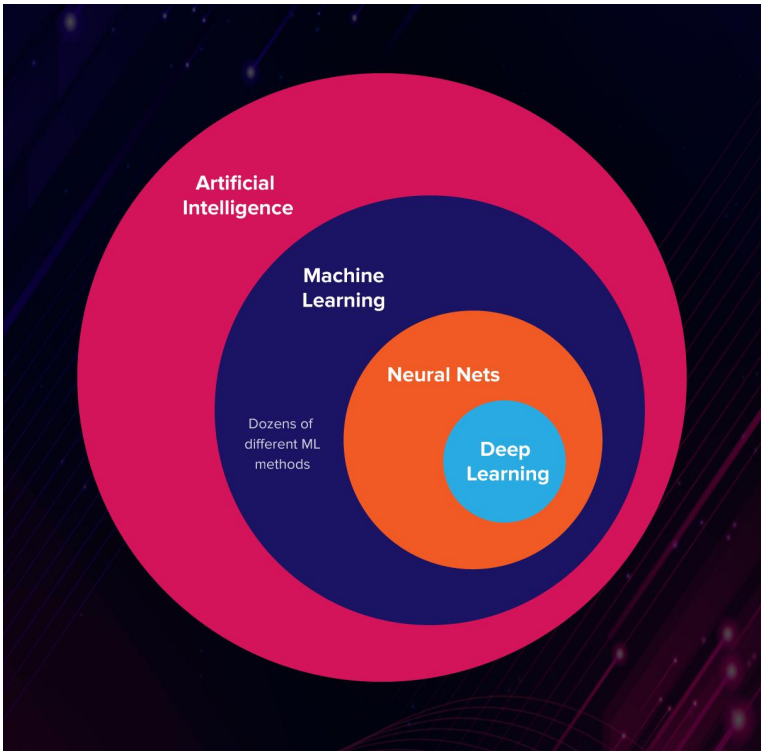

Figure 3.1: AI vs ML vs DL [8]

3.5.2 Using Machine Learning Methods

In the case of using machine learning for computer vision there are mainly 4 steps to execute, the first step is data preparation (preprocessing) in this step we need to preform some manipulations and transformations to clean the image data, some of these manipulations are cleaning noise, converting images to the same format, cropping, using gray scale instead of RBG...etc. each case requires its own set of manipulations and transformations. The second step is feature extraction which represents the hard work in most of the cases, in this step we extract a certain set of predefined features to be fed later to the algorithm, the third step is model training using the pre-labeled feature vectors, and the last step is predictions made for new image data, and for this we can choose from a variety of machine learning algorithms depending on our problem: Bayesian Nets, Decision Trees, Nearest Neighbors...etc [9].

3.5.3 Using Deep Learning

Applying deep learning in computer vision is totally different from applying classical machine learning algorithms, firstly, deep learning requires quantity (huge amounts of image data) over quality to have a robust model with accurate predictions, secondly neural networks saves us the trouble of feature extraction especially when using Convolution Neural Networks [32](Convolution: a mathematical operation on two functions to produce a third function [31]) this architecture of neural networks is specialized in processing image data and it is built on three primary layers Convolution layer, pooling layer and fully connected layer [9].

Convolution layer

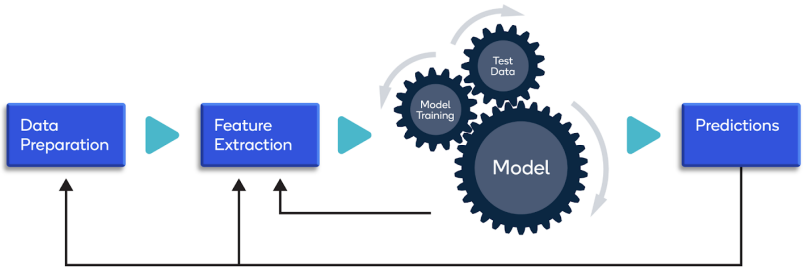

Figure 3.2: Machine Learning in Computer Vision [9]

This layer does most of the hard work by identifying and extracting the features, this is done by applying a filter of random size to blocks of the input image using the dot product between matrices.

pooling layer

After the feature extraction resulting from the Convolution layer we need to simplify (by reducing a bloc of values to a single value) the image for easy learning, there are 2 pooling operations max pooling and average pooling.

fully connected layer

It operates on a flattened input, where each input is connected to all the neurons, it is usually found at the end of the network connecting the hidden layers to the output which help in optimizing the class scores.

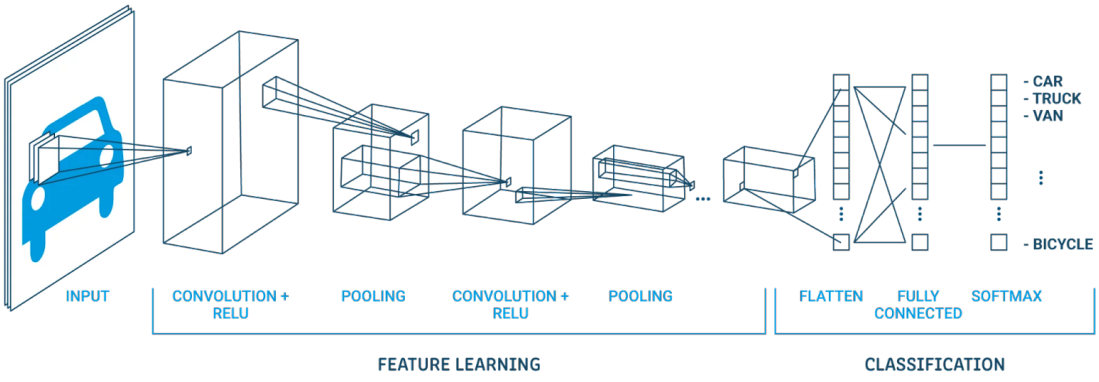

Figure 3.3: Deep Learning in Computer Vision [9]

3.5.4 Applications of Computer Vision

There are a lot of industries using computer vision and these are just a few examples [9]

medical imaging
It helps medical professionals interpret faster and diagnose abnormalities.

law enforcement and security
Like in surveillance and authentication.

self-driving machines
Like cars and robots.

gaming
Augmented reality and virtual reality.

pattern recognition

3.5.5 Some Technologies of Computer Vision

Because of the wide utility of computer vision and its benefits there are a lot of libraries and frameworks that facilitates a lot of the hard and repeated tasks, here we mention a few of them [9]

openCV
A python library for computer vision,

- super easy to use,
- a huge library of image processing algorithms,
- open source,
- works with GPUs

Tensorflow
made by Google and one of the most popular machine learning frameworks

- with a wide range of machine/deep learning algorithms,
- open source,
- GPU configured

PyTorch
made by Facebook, a neural network framework,

- used a lot by researchers,
- open source,
- works with GPUs

Caffe
a deep learning framework developed by Berkeley AI Research

- open source
- c++ based
- easy to use
- fast execution

Chapter 4

The Model

4.1 Introduction

Melanoma is a type of skin cancer, develops in the cells (melanocytes) that produce melanin — the pigment that gives your skin its color, The exact cause of all melanomas isn't clear, but exposure to ultraviolet (UV) radiation from sunlight increases your risk of developing melanoma. [33]

Melanoma is more dangerous because of its ability to spread to other organs more rapidly if it is not treated at an early stage. [34]

At present, CNN has achieved very good performance in the field of computer vision compared to other machine learning algorithms, such as object detection, image recognition, classification, etc.

"Convolutional Neural Network (CNN) is a type of deep learning model for processing data that has a grid pattern, such as images, which is designed to automatically and adaptively learn spatial hierarchies of features. CNN is a mathematical construct that is typically composed of three types of layers (or building blocks): convolution, pooling, and fully connected layers. The first two, convolution and pooling layers, perform feature extraction, whereas the third, a fully connected layer, maps the extracted features into final output, such as classification. A convolution layer plays a key role in CNN, which is composed of a stack of mathematical operations, such as convolution, a specialized type of linear operation." [35]

Because of the difficulty of detecting melanoma cancer in an ordinary way, CNN is used to classify melanoma skin cancer.

Research on the classification and detection of melanoma cancer by various methods has been carried out. In 2016 there was a paper entitled "Deep Residual Learning for Image Recognition" using the ResNet architecture. The paper was a winner at the 2015 ILSVRC (Imagenet competition). [36]

4.2 Proposed Convolutional Neural Network Model

The main aim of this implementation is to detect melanoma skin cancer through RGB images, to achieve this, we build a deep learning model that is capable of extracting features from the given dataset.

After delving into many articles and studies, we have found that the best convolutional neural network model we can suggest in this case is resnet50, and so we are going to

implement it from scratch. As shown in figure 4.1

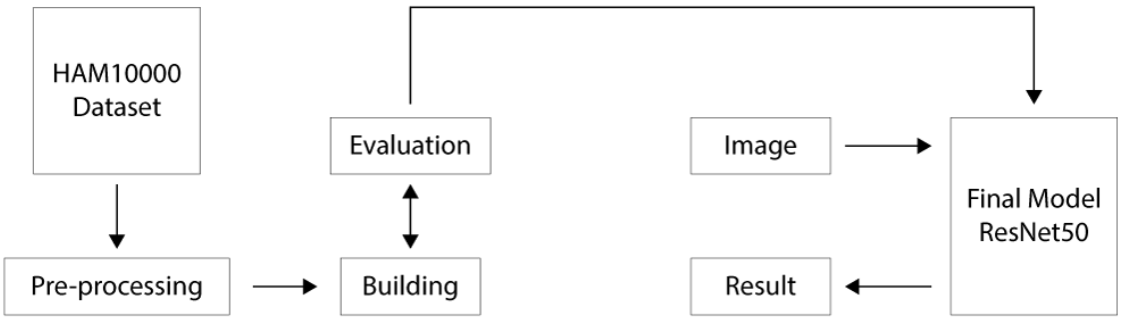

Figure 4.1: proposed architecture which we have used for melanoma recognition

4.3 Dataset (MNIST- HAM10000)

The ISIC archive is the largest public database for dermatoscopic image analysis research, and where the original HAM10000 was made available. [10]

The HAM10000 dataset is composed of 10.015 dermatoscopic images of pigmented skin lesions. The data was collected from Australian and Austrian patients. Two institutions participated in providing the images: Cliff Rosendahl in Queensland, Australia, and Medical University of Vienna, Austria. According to the authors, seven classes are defined on this dataset, where some diagnoses were unified into one class for simplicity. Information regarding patient age, sex, lesion location and diagnosis is also provided with each image. [10]

The dataset has been collated and published by Tschandl, P., Rosendahl, C. & Kittler, H. [10] A sample of each type of skin lesion present in the dataset is demonstrated in the figure 4.2. And the distribution of lesions is show in figure 4.3

4.4 Pre-processing

Before starting the model training process we need to process the dataset, as we learned earlier the dataset consists of around 10015 labeled images for 7 different types of skin lesions, but in our case, we want to get images classified on only two types of skin lesions (Melanoma and Not melanoma). We do this in several steps:

Data cleansing:

In this step, we remove unused and damaged data, also repair data that is incorrectly formatted.

Data separation:

After cleansing the data set, we separate the data set into two types of skin lesions

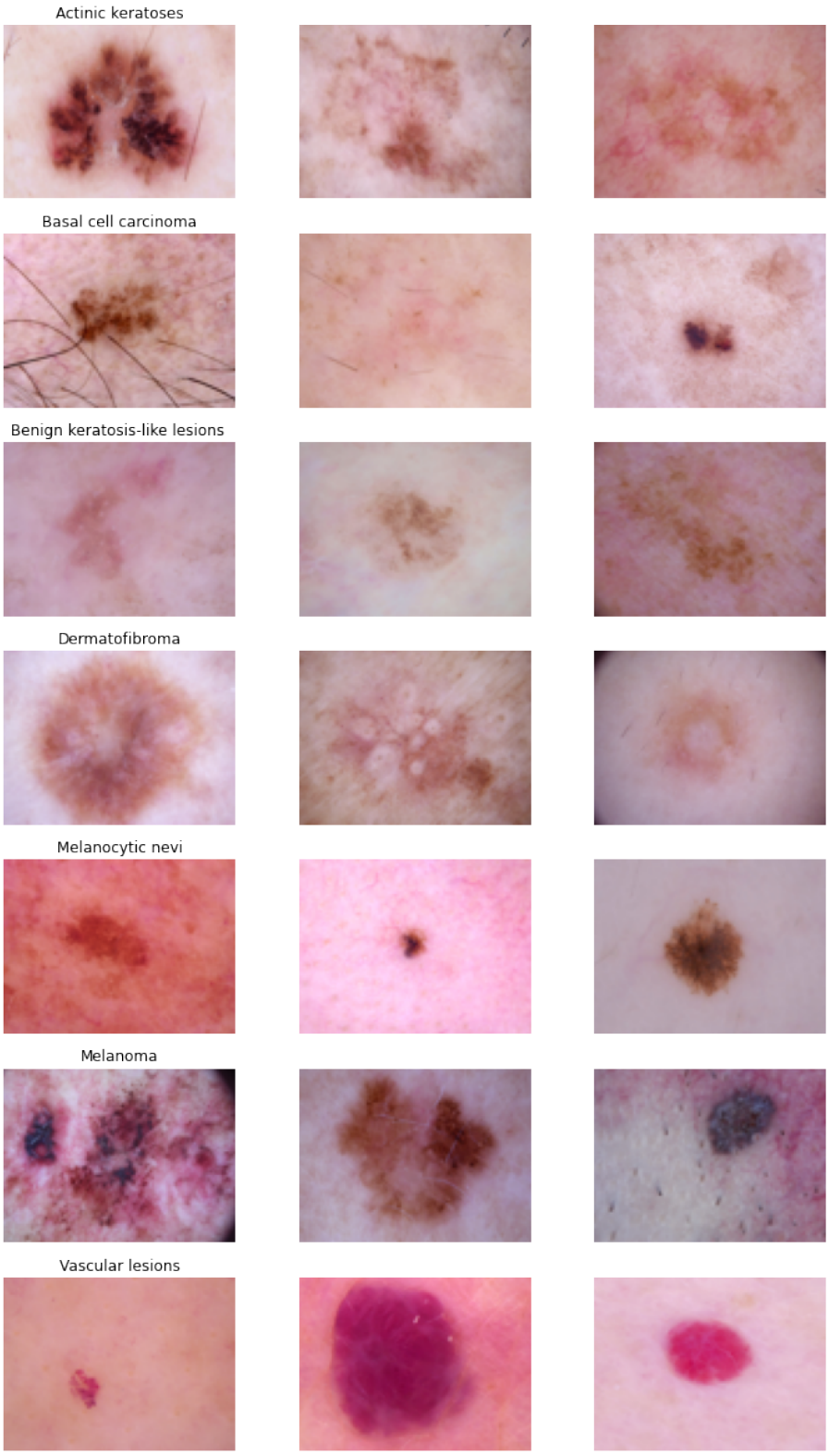

Figure 4.2: A sample of each type of skin lesion [10]

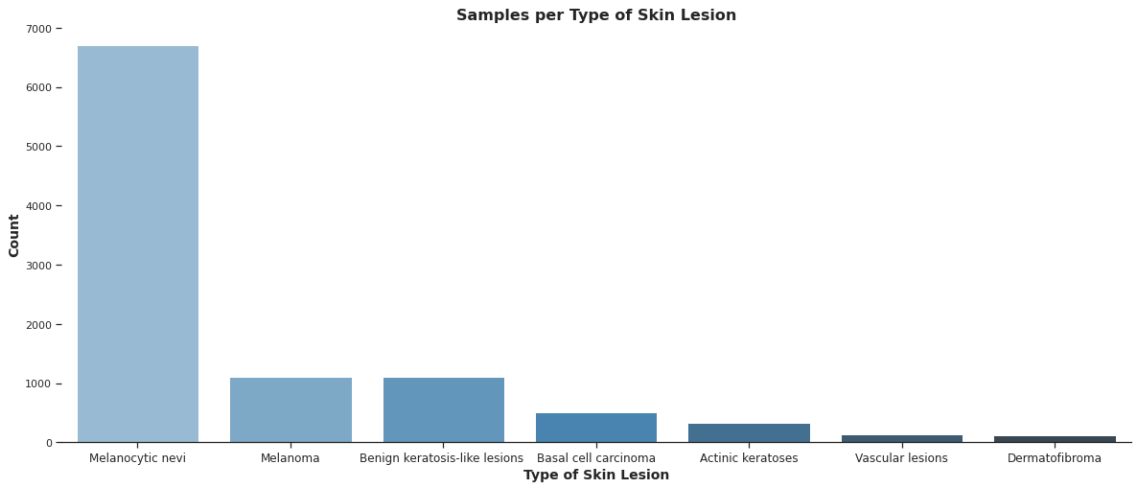

Figure 4.3: This count plot helps to understand the distribution of the data. [10]

by changing the data label for the non-melanoma types to non-melanoma, and we keep the data label for the type of melanoma as it is.

Data balancing:
When reclassifying the data set, we notice that the data set is numerically unbalanced. To solve this problem, we increase the number of images of the melanoma type by rotating, cropping and scaling. As for the non-melanoma type, we reduce the number of images by randomly selecting a specified number of images.

Image resizing:
In this step, we reduce the image size to 75*100 to speed up the training process of the deep learning model.

data splitting : Before the data set becomes usable, we divide it into two parts, the first part is the training set with 80 percent, and the second part is the test set with 20 percent

The diagram 4.4 helps to understand these steps

4.5 Experimental results

To judge the performance of the model for the task of predicting skin lesions, we use several evaluation metrics to evaluate our model. This is because the model may perform well using one measurement from one evaluation metric, but may perform poorly using another measurement from another evaluation metric. Using evaluation metrics is critical in ensuring that our model is operating correctly and optimally.

When the model was trained for 30 epochs, it was observed that the accuracy for both the training and test data started with rather large values and continued to increase slowly from epoch 4 until it reached its peak in epoch 30 (which goes to show that our chosen artchitecture is very good for this task). The test accuracy reached 93 percent and the training accuracy was 97 percent.

The plot for the accuracy and loss obtained during the training and testing process is shown in Figure 4.5

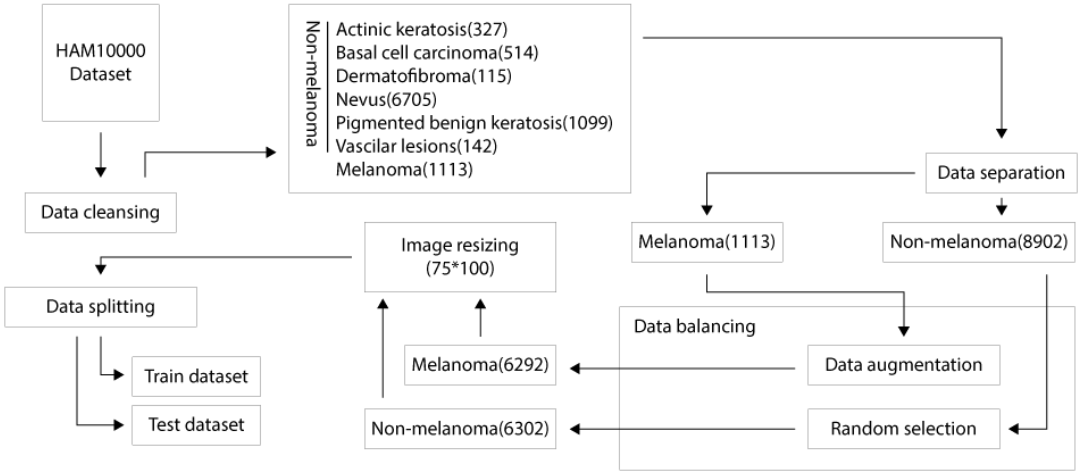

Figure 4.4: Pre-processing

The table 4.1 also includes several other measurements that we used in evaluating our model

Classes	Precision	Recall	F1-score	Support
Non-melanoma	0.95	0.93	0.94	1293
Melanoma	0.93	0.95	0.94	1226

Table 4.1: Evaluation Measures

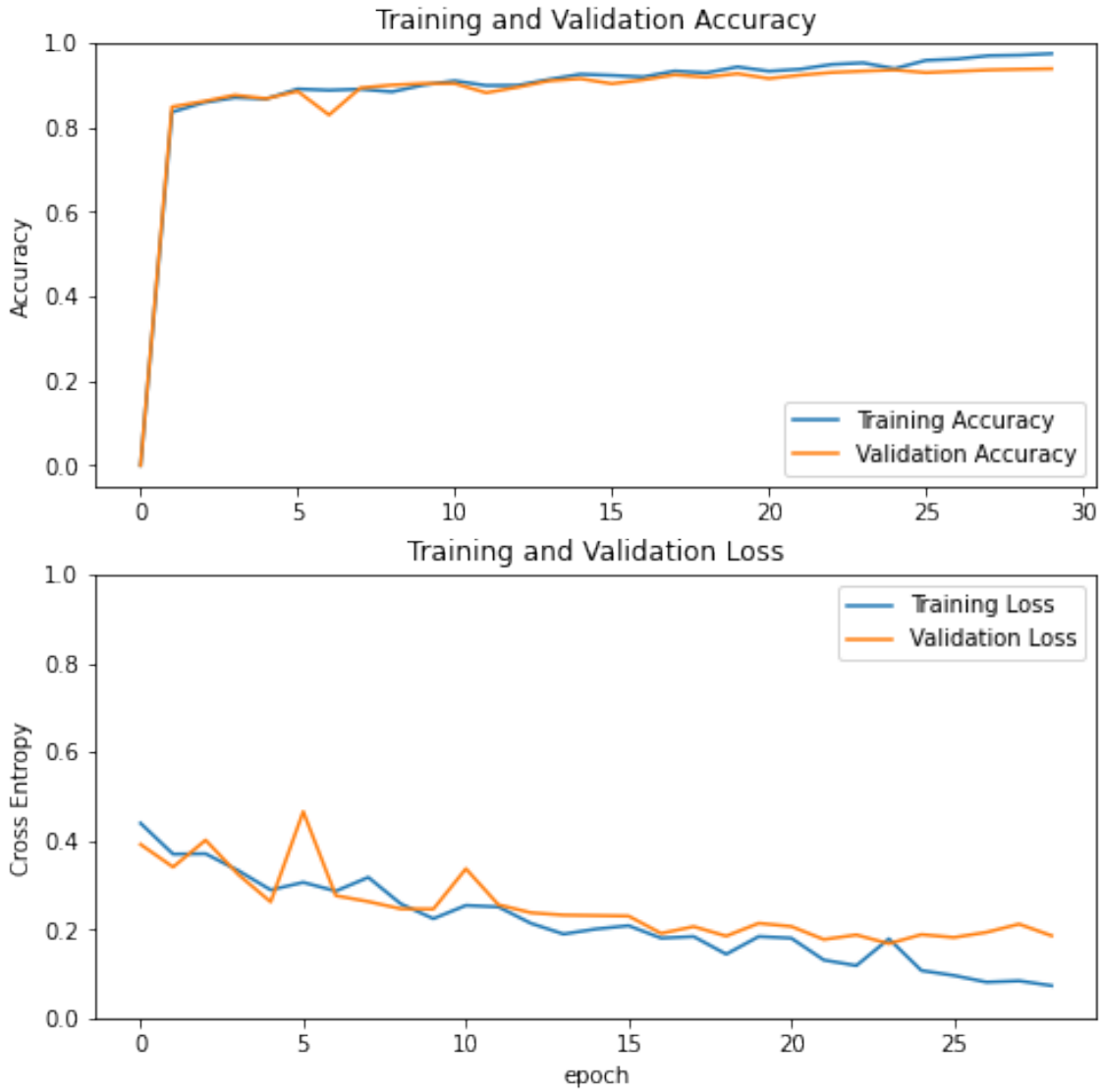

Figure 4.5: Accuracy and Loss

Chapter 5

The Diagnosis System

5.1 Conception

5.1.1 Introduction

The idea of our project is as follows:
We wanted to come up with an easy way to check whether you have melanoma or not, without the need to go to a doctor, or you can use it as a second confirmation before or after you go to a dermatologist. And what is easier than a web application that you can access from anywhere and at anytime.

Our product can be used in 2 scenarios. Either by normal persons that are suspicious of having melanoma, they can use the application to decide whether to go to a dermatologist for further testing and confirmation. The second scenario is the use of this application by doctors to help them in the diagnosis process without having to do a lot of testing just to get initial results, you can think of the application as the replacement of the doctor's naked eye analysis, and after that he/she can decide whether to do more extensive testing such as biopsies. And as an added feature every user of the application can decide whether or not to publish his lesion image, which will then be accessible to all the doctors inside the application, and they can comment on it and give their professional opinion, after that the user can communicate with a doctor using the in-application messaging feature, to get more information or to make an appointment

In the next sections, we are going to present a set of diagrams that will explain the design of our web-based platform for skin cancer diagnosis.

5.1.2 Class Diagram

Class diagrams may be used to represent the system's constituent parts, show the connections between them, and offer information on the functions and services each one of them performs. The system design process benefits from class diagrams at various phases.

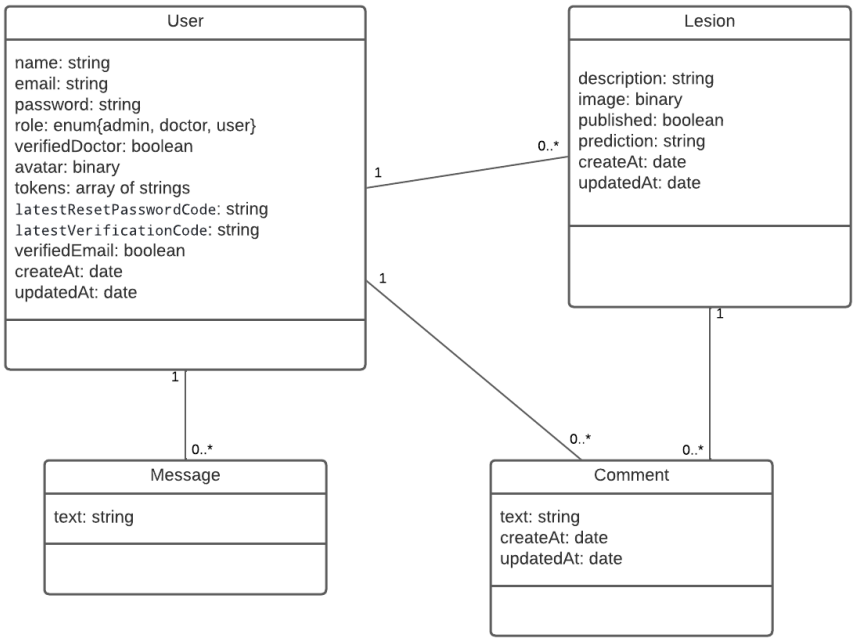

Figure 5.1: Class Diagram

5.1.3 Use Case Diagram

An effective technique to condense information about a system and the users within it is to create a use case diagram. It is often displayed as a visual representation of how various system components interact with one another.

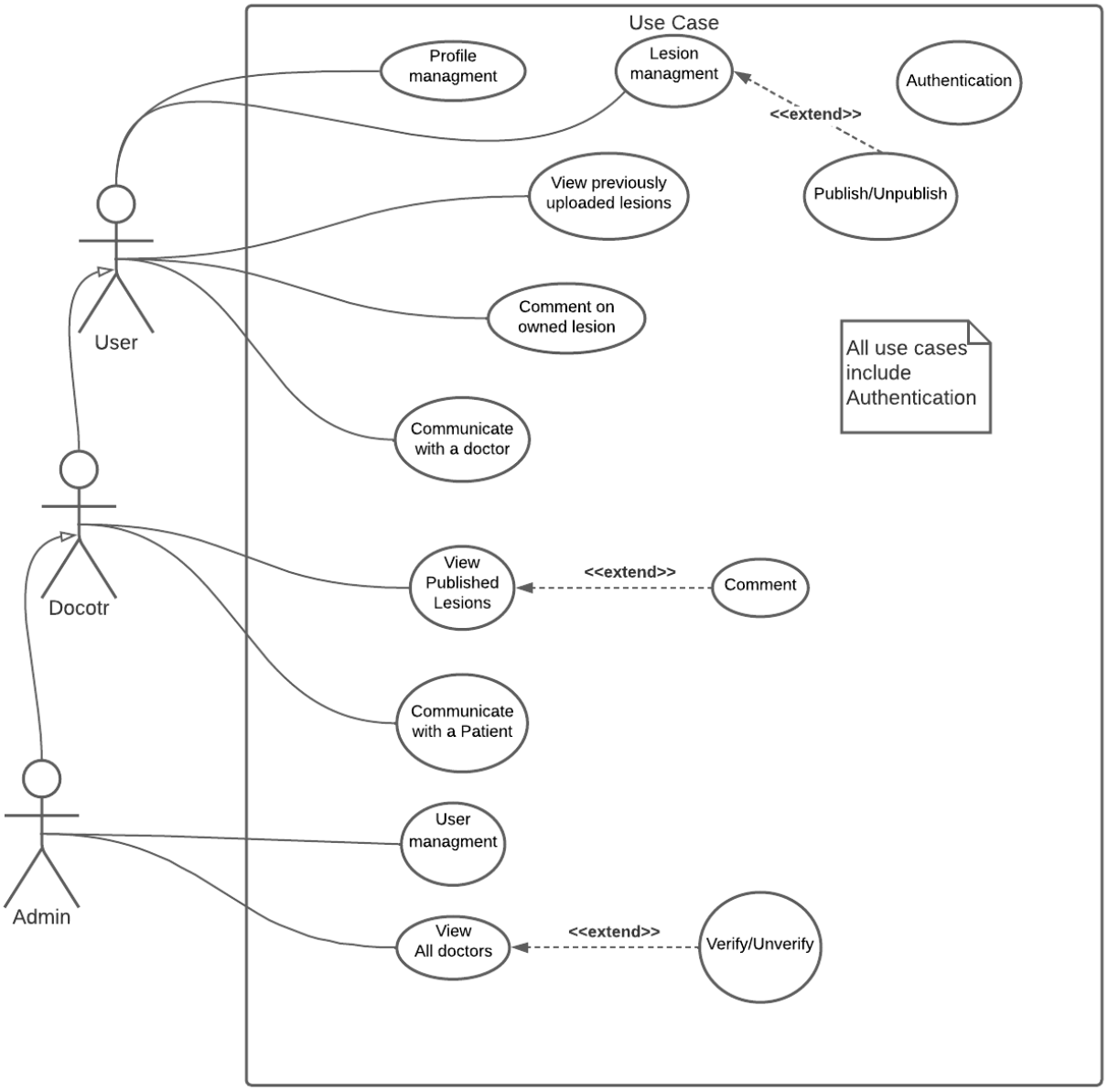

Figure 5.2: Use Case Diagram

5.1.4 Component Diagram

An illustration of how components are linked together to create bigger components or software systems is called a component diagram. They serve as examples of how arbitrarily complex systems are structured.

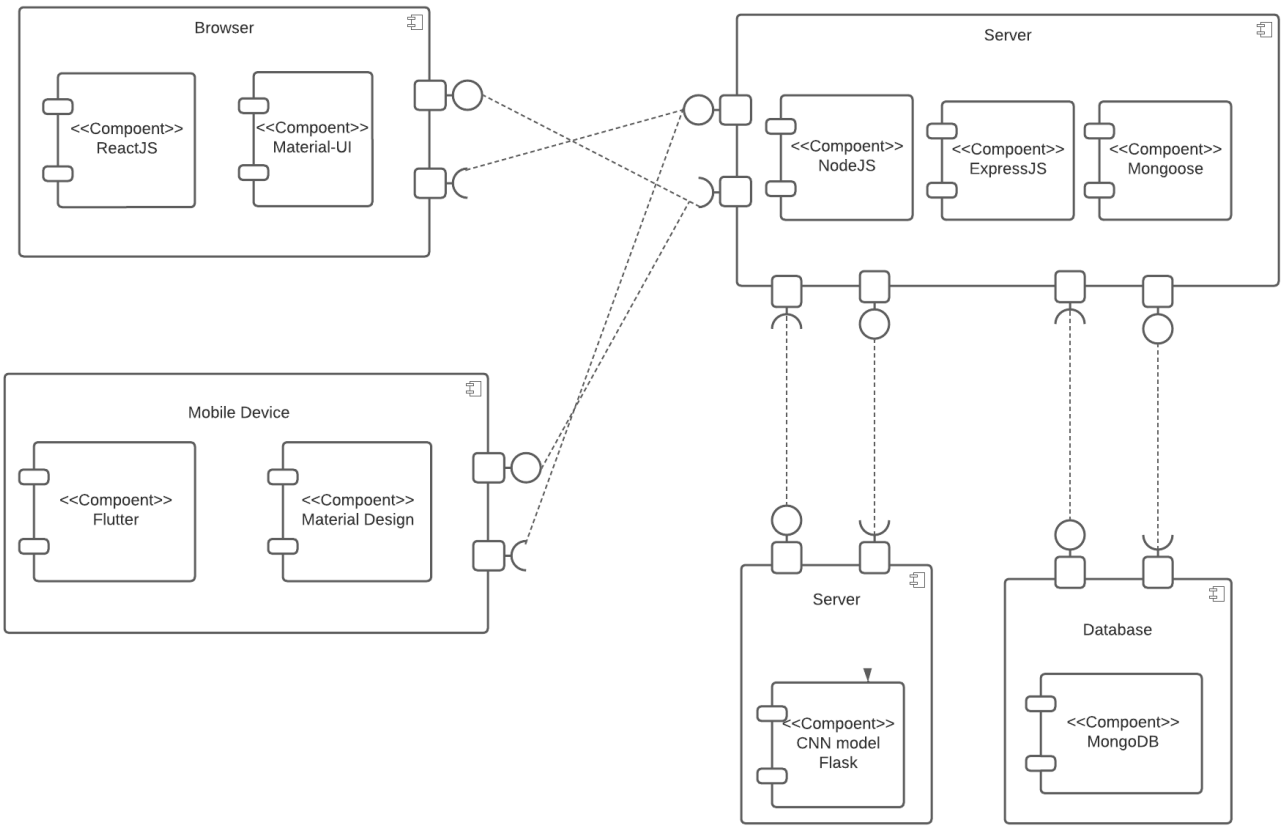

Figure 5.3: Component Diagram

5.1.5 Deployment Diagram

A deployment diagram is a type of UML diagram that displays the system's execution architecture, including the middleware connecting the nodes—such as hardware or software execution environments—and the nodes themselves. Typically, deployment diagrams are used to illustrate a system's actual hardware and software.

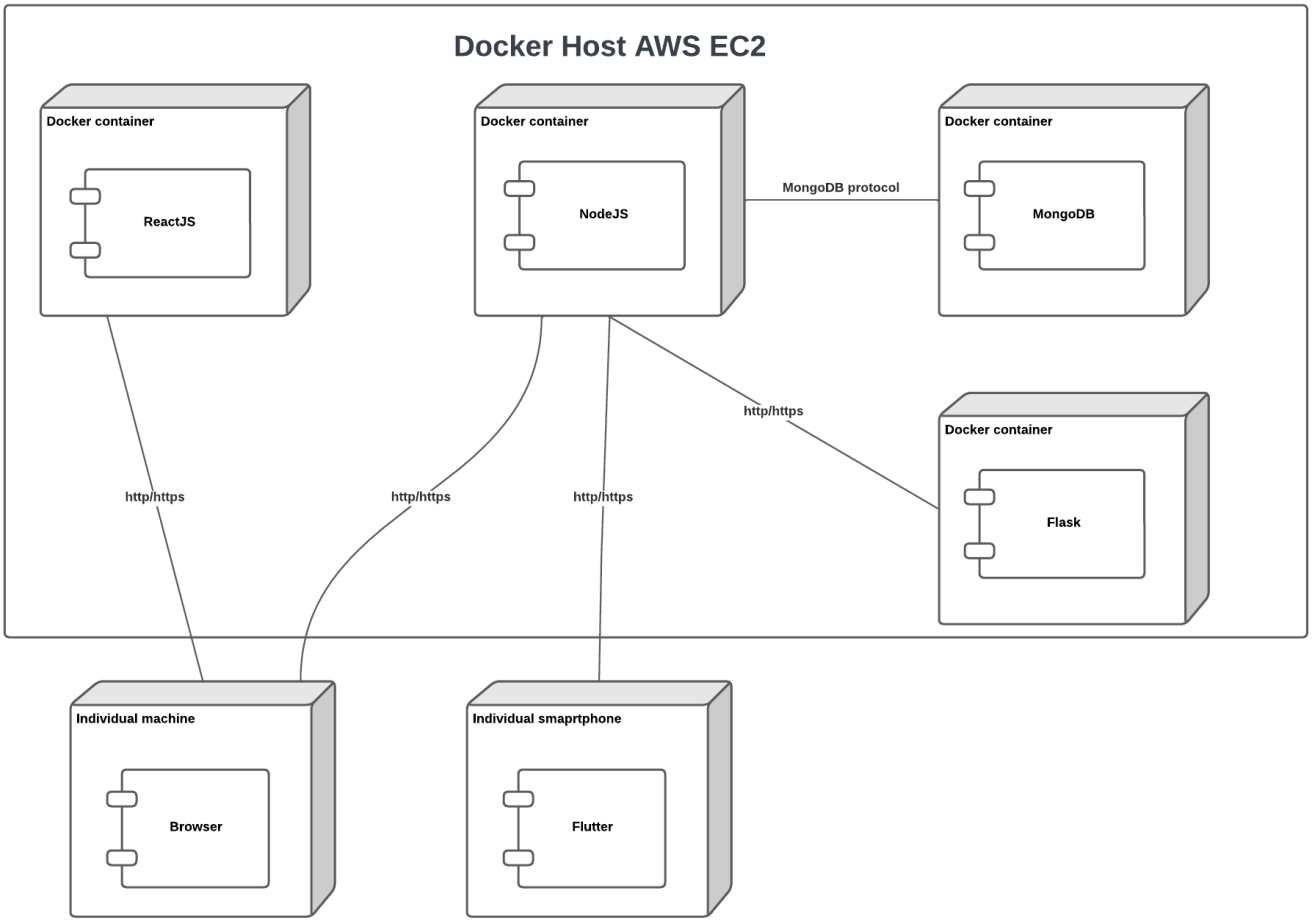

Figure 5.4: Deployment Diagram

5.2 Presentation of the Web-based Platform

5.2.1 Introduction

In this section we are going to talk about the different tools and resources that helped us build our project, we will talk about the software, hardware and explain in detail the features of the web application and finally present the interface.

5.2.2 Hardware

This project is a 2-person teamwork, we were able to implement it using 2 laptops:

Asus vivobook: with an intel CPU i7 7nth generation with a clock rate of 2.7GHz and an Nvidia GPU GeForce 930mx, 12 GB of RAM and 240 GB of Solid State Drive, with a Linux Mint 20.3 Cinnamon operating system

Dell XPS: with a 7th Generation Intel Core i7-7700HQ Quad Core Processor (6M cache,

up to 3.8 GHz) and NVIDIA GeForce GTX 1050 4GB DDR5 Graphics that was used to train the CNN model , 16 GB RAM DDR4-2400MHz and 512 GB PCIe Solid State Drive, with a Windows 10 Professional edition operating system

5.2.3 Software

The implementation of the project was achieved using various frameworks and libraries, and from those we mention the following:

- 1
- 2
- 3
- 4

5.2.4 The Web Application

Authentication

The Authentication was implemented using JWTs (JSON web tokens) which is acquired by the frontend client after Logging in or Signing up, after that it will be saved in a session storage and sent as an Authorization header with each request that requires authentication, in the backend the tokens are saved in an array to allow for multiple session communication, which means that a user can connect from multiple devices, with the ability to logout from all sessions being available in the profile settings.

Permissions and Roles

There are mainly 3 roles in our application: Admin, Doctor, User. Each one of these roles comes with a certain level of access. The permissions were implemented using ExpressJS middleware, the list of permissions goes as follows,

Admin :

- User management.
- View all doctors
- Doctor verification, through credentials sent by e-mail.

Doctor :

- View published lesions.
- Comment on a published lesion
- Communicate with a patient

User :

- Profile management.
- Upload a lesion.
- Publish/Unpublish a lesion
- View own lesions
- Comment on own lesion
- Communicate with a doctor

Keep in mind that the Admin also has the permissions of the doctor, and a Doctor also has the permissions of a normal user.

Communications Between Different Parts Of The Application

We divided our application 2 frontends and 2 backends and a database, 2 frontend clients one for a browser(ReactJS) and one for a smartphone (Flutter), these 2 communicate with the main backend (NodeJS) using Rest API architecture and http/https protocol. and the main backend communicates with the 2nd backend (flask) which has the implementation of the CNN prediction model also using Rest API architecture and http/https protocol, and with the database server using MongoDB protocol.

The CNN model is used when a user uploads a lesion image to the NodeJS backend, and after that the Node server sends the image to the model and receives a prediction string from it which after that saved in the database and returned to the frontend client.

Hosting

As it is show in the deployment diagram figure 5.4, we have hosted our project in an AWS EC2 server combined with Docker, in other words, the Docker engine is hosted in AWS and our software parts are distributed in various docker containers. We have chooses docker to facilitate the deployment process, and benefit from the DNS server provided inside the docker engine between the containers, which allows us to use host names to connect different parts of our software instead of IP addresses, docker also provides better resource consumption and better network security that allows us to control what we expose to the public. Containers are easy to maintain, a change in one container will not affect the other containers, and as a final point if we ever decide to change the hosting provider docker makes that easy, all we need is the configuration of docker and the data of our users, and we are all set.

5.2.5 The Interface

We present the application's interface in the following figures:
First of all, the following 2 figures demonstrate the Login and Signup interfaces:
you can log in with Email and Password, or Signup providing Name, Role, Email, Password

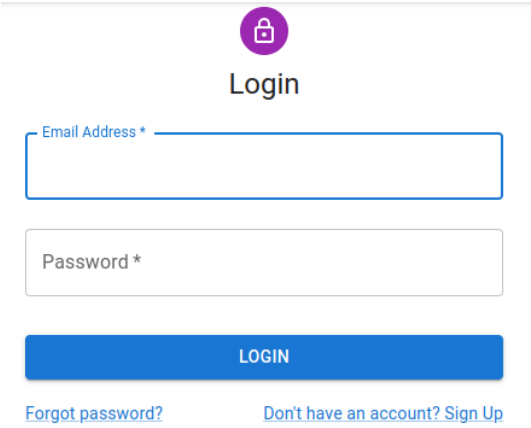

Figure 5.5: Login

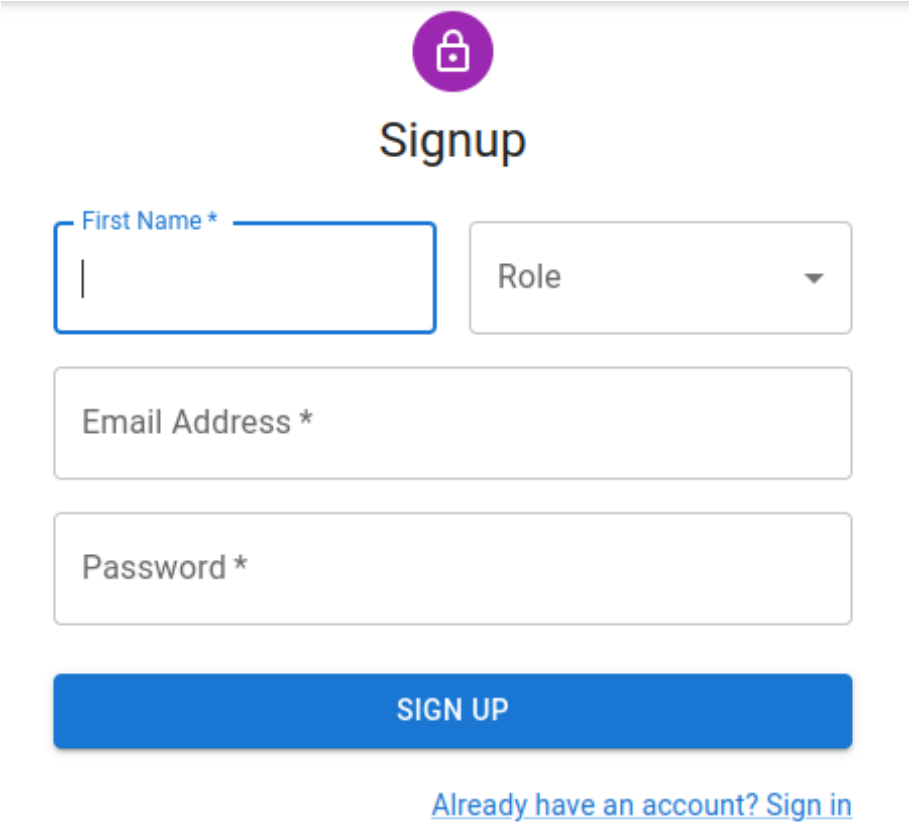

Figure 5.6: Signup

The following interfaces are in the Profile page:
You can view profile information, upload a profile image, and delete your account

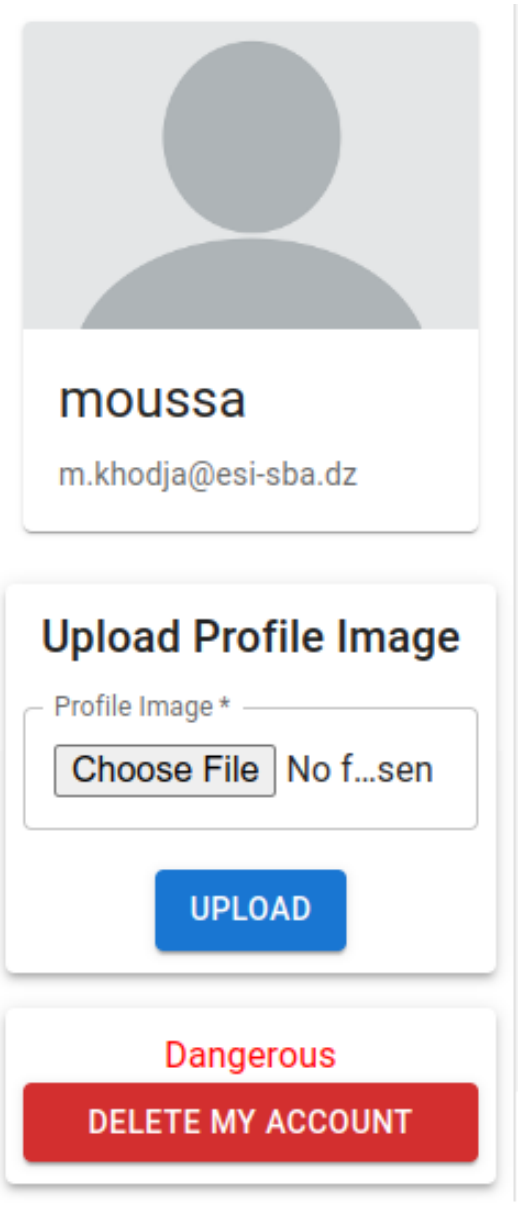

Figure 5.7: Profile Settings

This component allows you to upload a lesion image with a description

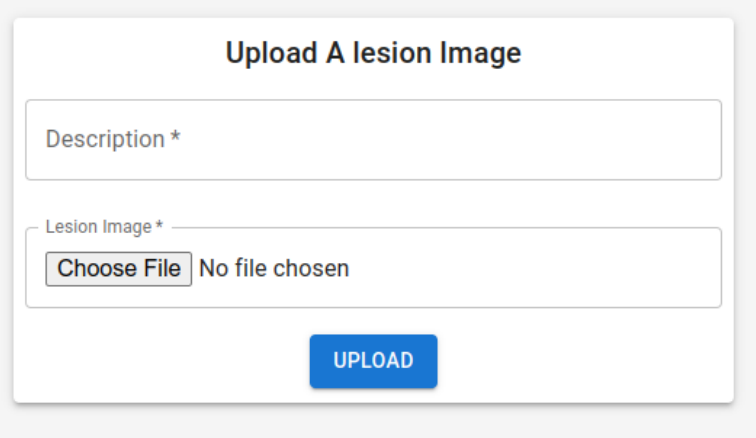

Figure 5.8: Upload a lesion Image, with a description

The following interfaces are found in the Forum page:
You can view all lesions that were published by patients, and give your professional opinion by leaving a comment, you can also view comments from other doctors

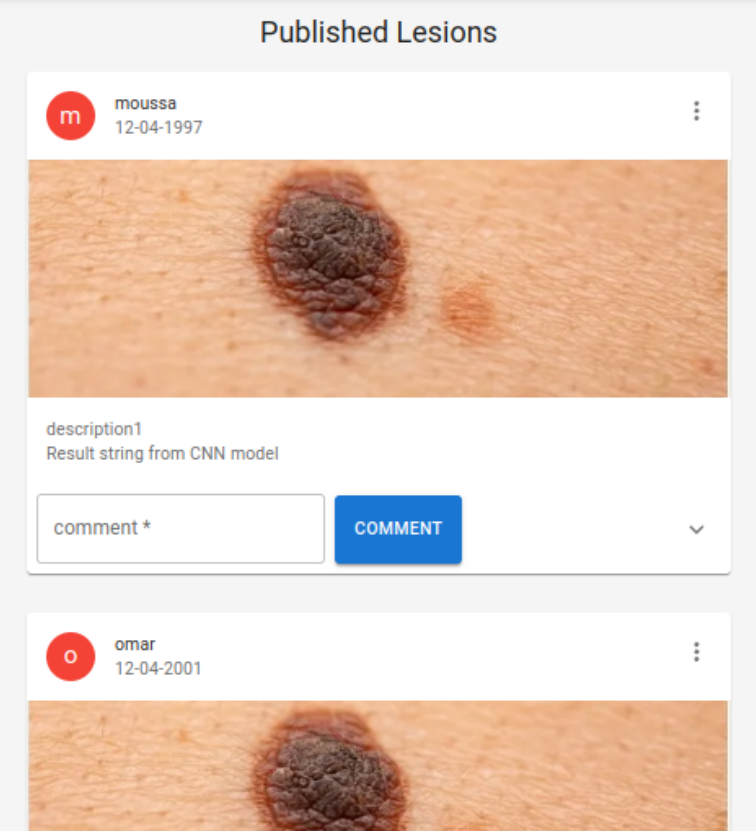

Figure 5.9: View published lesions as a doctor

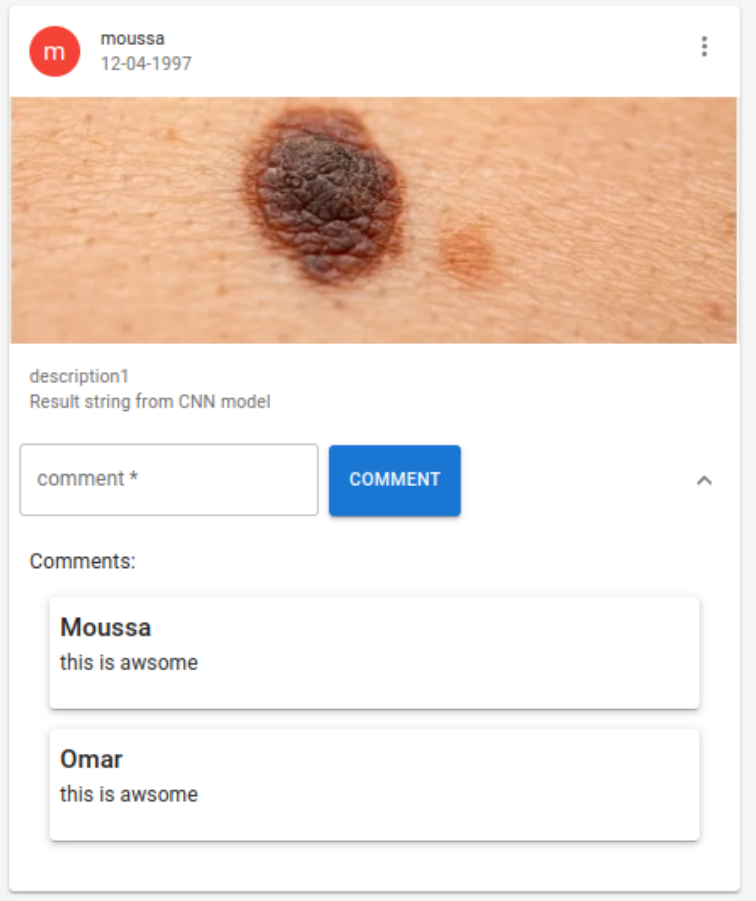

Figure 5.10: Comment on a lesion

This interface represents the Communication page:
You can send and receive messages, between doctors and patients

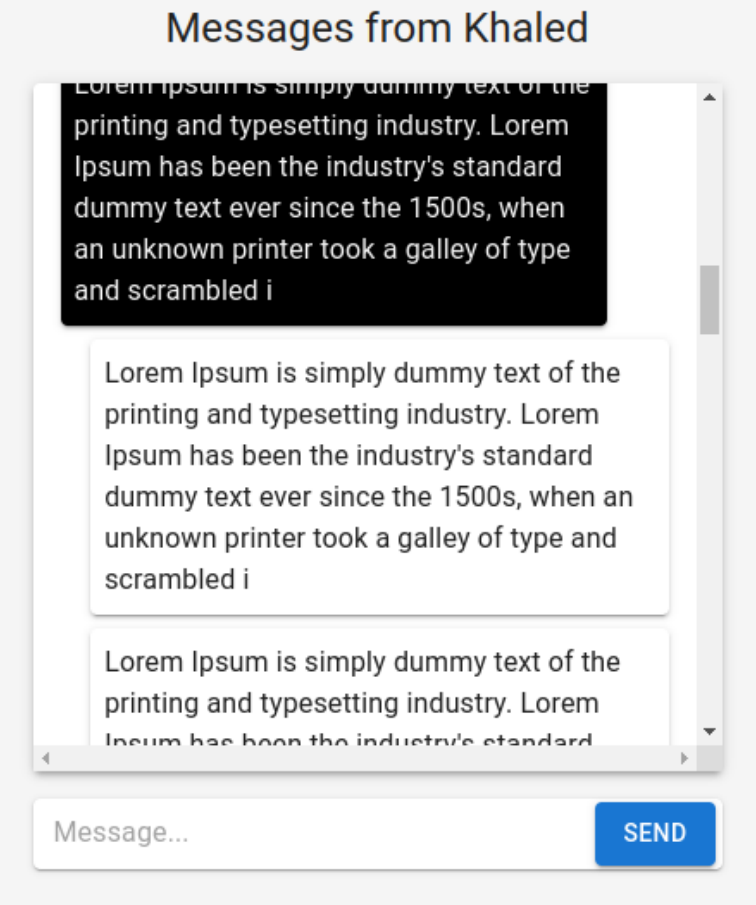

Figure 5.11: Messaging

The following interfaces are found in the dashboard:
After checking the credentials sent by email, the admin can verify a doctor's account, because a non-verified doctor is considered as a normal user, and he can't access patients information

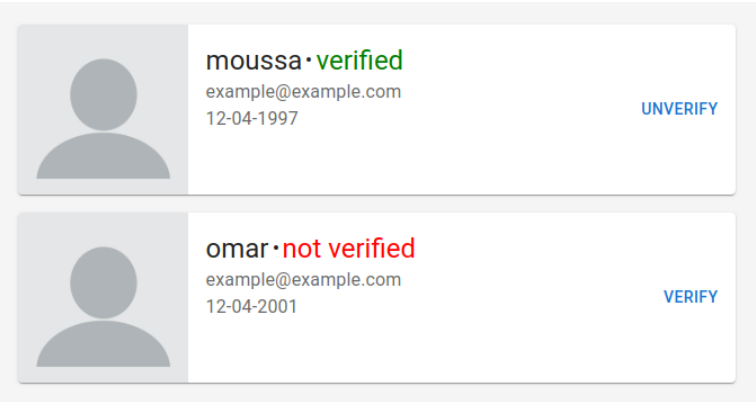

Figure 5.12: View all doctors by Admin + verify/unverify a doctor

5.2.6 Future Work

we present these ideas as a future work to extend the usability of our project

- Detect and classify more lesions and not just melanoma.
- Take model interpretability into account, so it will be more acceptable in real world scenarios.
- Present more in-app features to facilitate and enhance user experience.

Chapter 6

Conclusion

Skin cancer is one of the most dangerous and widespread cancers in the world, it can occur to anyone of any age and of any race, just by standing in the sun for too long will increase your chances of getting it. That is why an early diagnosis will save your life. Here where the CAD's (computer aided diagnosis) systems would play an important role by implementing machine learning algorithms that could recognize, detect and classify various skin lesions. Advancements in both machine learning and deep learning have produced a lot of models that reach an accuracy above that of an expert dermatologist, but we can't do without the expertise of specialized doctors.

In this article we have presented a diagnosis system that could facilitate the process of detection and early discovery of melanoma skin cancer, it is web-based, easy to use and accessible to everyone, all you need is internet connection, a laptop or a smartphone, and you are set to go. It can either be used by normal users who think that they might have melanoma, they can check that using the app before actually going to a doctor and do invasive tests (such as biopsy), or it can be used by doctors to facilitate the process of diagnosis and improve patients experience.

Bibliography

[1] Skin, cleveland clinic. https://my.clevelandclinic.org/health/articles/10978-skin.

[2] Hair and human skin anatomy. https://www.vecteezy.com/vector-art/3190201-hair-and-human-skin-anatomy.

[3] Skin barrier basics for people with eczema, national eczema association. https://nationaleczema.org/what-is-my-skin-barrier/.

[4] Vitamin d and the skin: Focus on a complex relationship. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4642156/.

[5] What is a mutation? https://www.yourgenome.org/facts/what-is-a-mutation.

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

[7] Differences between a malignant and benign tumor, verywell health. https://www.verywellhealth.com/what-does-malignant-and-benign-mean-514240.

[8] Yulia Gavrilova. Artificial intelligence vs. machine learning vs. deep learning: Essentials, serokell.io. https://serokell.io/blog/ai-ml-dl-difference, 2020.

[9] Vihar Kurama. Ml-based image processing, nanonets. https://nanonets.com/blog/machine-learning-image-processing/, 2021.

[10] JULIANA NEGRINI DE ARAUJO. Ham10000: Analysis and model comparison. https://www.kaggle.com/code/jnegrini/ham10000-analysis-and-model-comparison/notebook, 2021.

[11] Cancer, world health organization. https://www.who.int/news-room/fact-sheets/detail/cancer.

[12] Elin Jørgensen, Giulia Lazzarini, Andrea Pirone, Stine Jacobsen, and Vincenzo Miragliotta. Normal microscopic anatomy of equine body and limb skin: A morphological and immunohistochemical study. *Annals of Anatomy*, 218:205–212, 7 2018.

[13] Joseph M. Abdo, Nikolai A. Sopko, and Stephen M. Milner. The applied anatomy of human skin: A model for regeneration, 3 2020.

[14] Sarah A Mohamed and Rachel Hargest. Surgical anatomy of the skin, 2021.

[15] Eliana B. Souto, Joana F. Fangueiro, Ana R. Fernandes, Amanda Cano, Elena Sanchez-Lopez, Maria L. Garcia, Patrícia Severino, Maria O. Paganelli, Marco V. Chaud, and Amélia M. Silva. Physicochemical and biopharmaceutical aspects influencing skin permeation and role of sln and nlc for skin drug delivery, 2 2022.

[16] What is cancer?, national cancer institute. https://www.cancer.gov/about-cancer/understanding/what-is-cancer, 2021.

[17] Mahsa Alidoust Saharkhiz Lahiji and Fatemeh Safari. Potential therapeutic effects of hamscs secretome on panc1 pancreatic cancer cells through downregulation of sgk269, e-cadherin, vimentin, and snail expression. *Biologicals*, 2022.

[18] Rachita Pandya, Kaitlyn Grace San Diego, Talha Shabbir, Arnav P. Modi, Justin Wang, Joseph Dhahbi, and Sanford H. Barsky. The cell of cancer origin provides the most reliable roadmap to its diagnosis, prognosis (biology) and therapy. *Medical Hypotheses*, 157, 12 2021.

[19] Skin cancer 101, skin cancer foundation. https://www.skincancer.org/skin-cancer-information/, 2022.

[20] Skin cancer (non-melanoma), nhs. https://www.nhs.uk/conditions/non-melanoma-skin-cancer/, 2020.

[21] By Mayo Clinic Staff. Skin cancer, mayo clinic. https://www.mayoclinic.org/diseases-conditions/skin-cancer/symptoms-causes/syc-20377605, 2020.

[22] Cancer, wikipidia. https://fr.wikipedia.org/wiki/M%C3%A9lanome, 2022.

[23] Squamous cell carcinoma, walk-in dermatology. https://walkindermatology.com/patient-education/squamous-cell-carcinoma/.

[24] First immunotherapy for advanced basal cell carcinoma approved in us, european pharmacautical review. https://www.europeanpharmaceuticalreview.com/news/142524/libtayo-first-immunotherapy-for-advanced-basal-cell-carcinoma-approved-in-us/, 2021.

[25] Skin cancer prevention, skin cancer foundation. https://www.skincancer.org/skin-cancer-prevention/, 2022.

[26] By Mayo Clinic Staff. Skin cancer diagnosis, mayo clinic. https://www.mayoclinic.org/diseases-conditions/skin-cancer/diagnosis-treatment/drc-20377608, 2020.

[27] Artificial intelligence, built in. https://builtin.com/artificial-intelligence.

[28] JAKE FRANKENFIELD. Turing test, investopedia. https://www.investopedia.com/terms/t/turing-test.asp, 2022.

[29] machine learning, built in. https://builtin.com/machine-learning.

[30] Deep learning: An in-depth look into the ai-based tech, built in. https://builtin.com/artificial-intelligence/deep-learning.

[31] What is computer vision?, ibm. https://www.ibm.com/topics/computer-vision.

[32] machine learning in computer vision, full scale. https://fullscale.io/blog/machine-learning-computer-vision/, 2019.

[33] By Mayo Clinic Staff. Melanoma, mayo clinic. https://www.mayoclinic.org/diseases-conditions/melanoma/symptoms-causes/syc-20374884, 2022.

[34] Melanoma overview, skin cancer foundation. https://www.skincancer.org/skin-cancer-information/melanoma/, 2022.

[35] Yamashita Rikiya, Mizuho Nishio, Do Richard Kinh Gian, and Kaori Togashi. Convolutional neural networks: an overview and application in radiology. *Insights Into Imaging*, 9, 2018.

[36] Arief Budhiman, Suyanto Suyanto, and Anditya Arifianto. *Melanoma Cancer Classification Using ResNet with Data Augmentation*. 2019.