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**COMPARATIVE STUDY OF MACHINE
LEARNING METHODS USED FOR SKIN
CANCER DETECTION AND CLASSIFICATION**

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Abstract

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Chapter 1

General Introduction

Chapter 2

General Medecal Information

2.1 Skin

The skin is a complex organ a [11], it is interactive, self renewing and represents the first and primary defense line against hostile environment and it has several characteristics such as selective absoption, auto regeneration when injured, barrier to water loss, touch sensitivity ...etc [12]. It represents the largest sensory organ (15% of total body weight and a total area of 1.86 m²) [13], 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 [14].

2.1.1 Skin Anatomy

The skin is primary composed of 3 main layers as shown in the figure 2.1, each layer has its unique properties and functions [13].

Epidermis the outer most layer which is constantly regenerating and it contains the pigment melanin that determins the skin color and it also represents a physical and biological barrier

Dermis the middle layer, it supports the flexibility and gives strength the epidermis and it is maily 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 absoption

2.1.2 Other entities also contained in the skin

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

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

there anatomies are shown in the figure 2.2

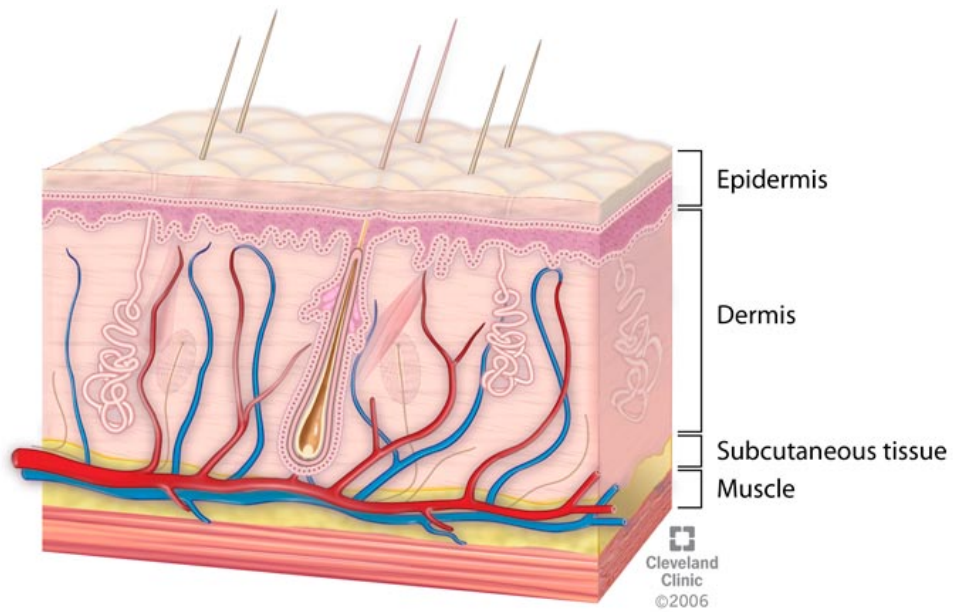


Figure 2.1: Skin Anatomy [1]

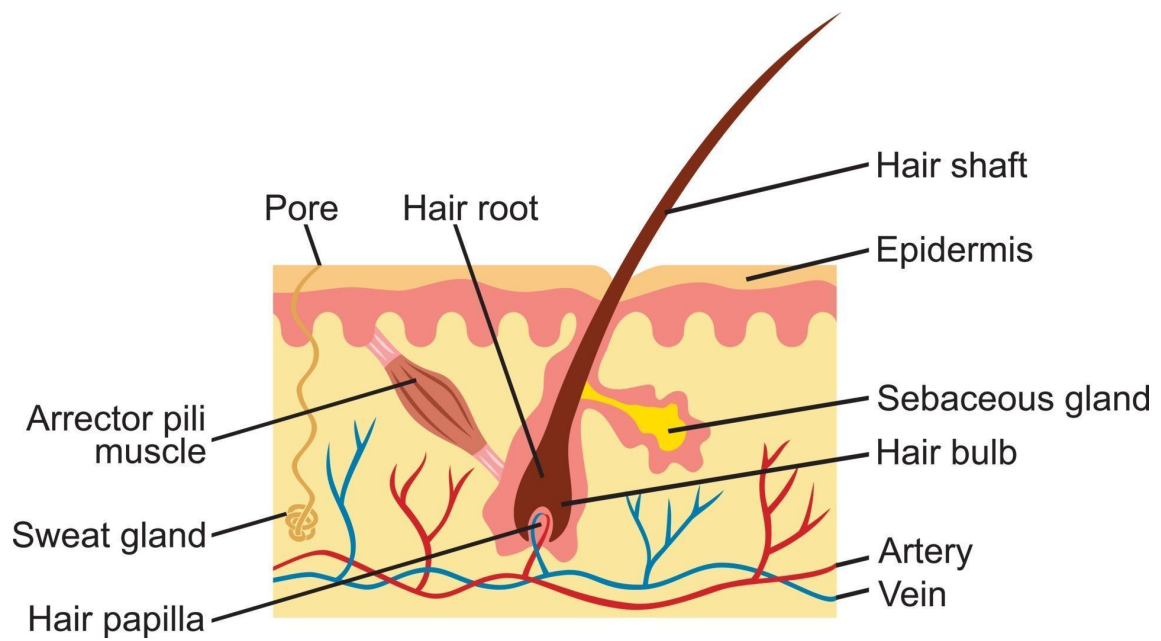


Figure 2.2: Hair and Sweat Glands Anatomy [2]

2.1.3 Functions of the Skin

The skin has 6 main functions that can be summarized as follows [13]

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 ultra-violet light protection [12]) 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 it 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 (18-20% of total body water) 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 [12] as shown in figure 2.4

2.2 Cancer

Cancer is an illness caused by the uncontrolled division and spreading of normal cells [15] 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 [16]. 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 [17]

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

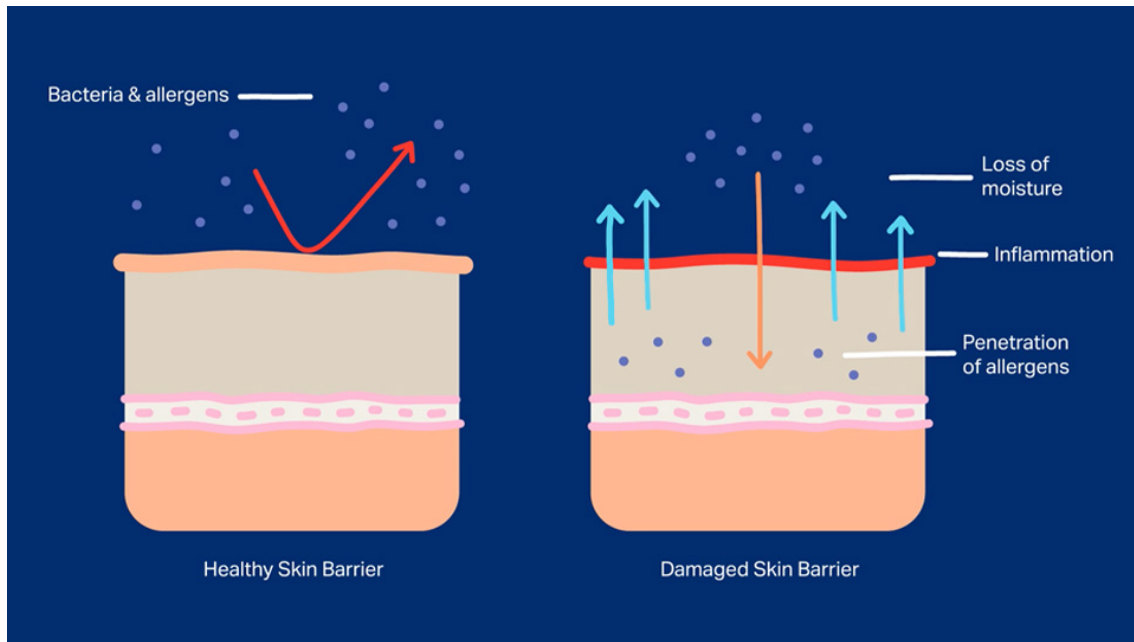


Figure 2.3: Protective/moisture Barrier Functions [3]

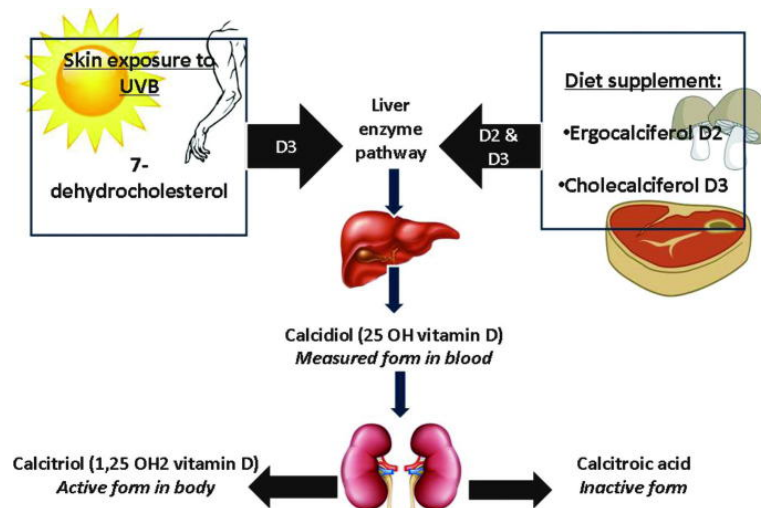


Figure 2.4: Hair and Sweat Glands Anatomy [4]

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 [10]

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 [17]. 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 [15]

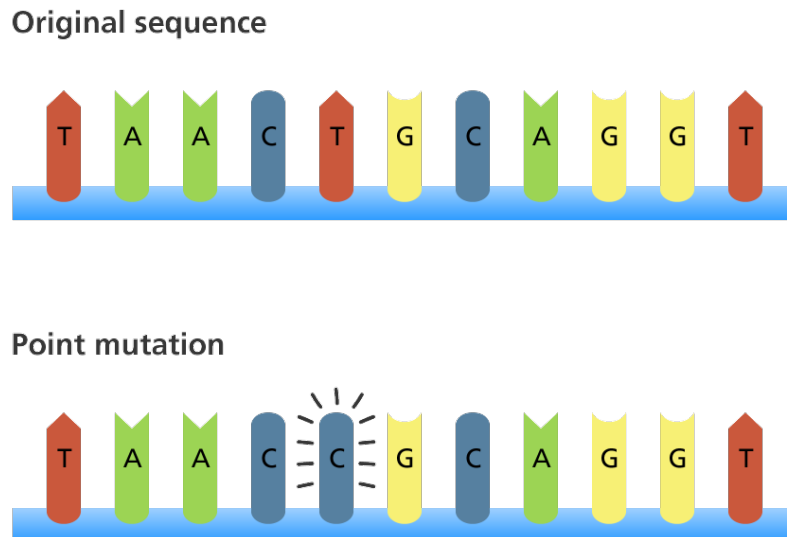


Figure 2.5: DNA Mutation [5]

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 [15] 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 [15] 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 [15].

carcinoma most common type formed by epithelial cells

sarcoma form in bone and soft tissue

leukemia form in bone marrow, this type does form a tumor but travels in the blood

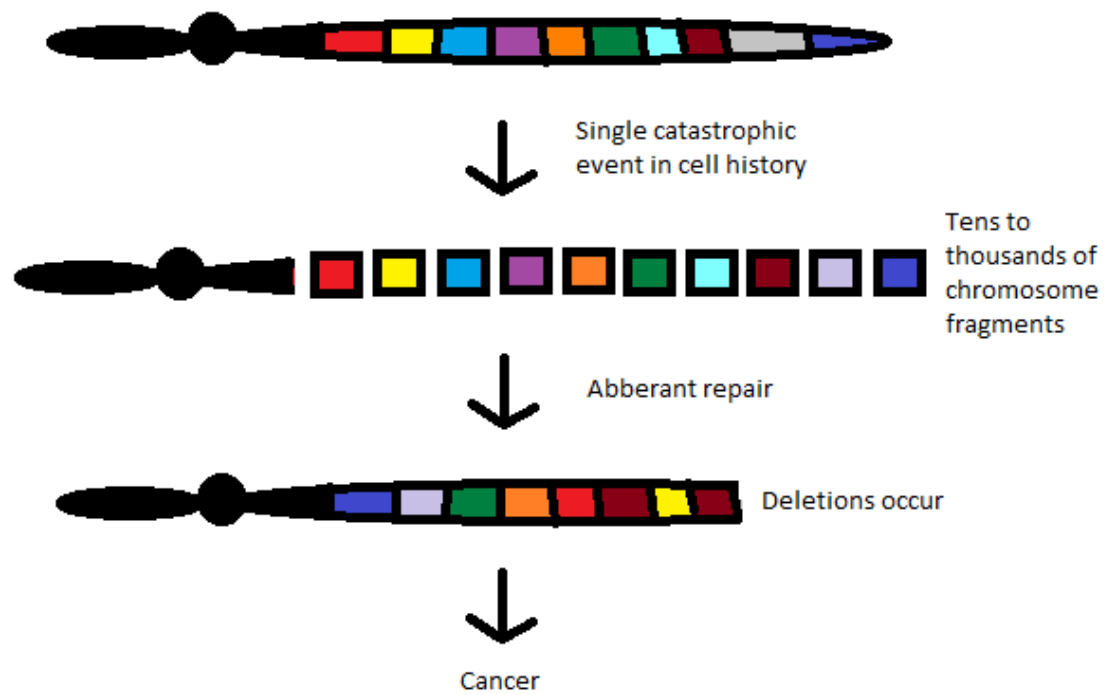


Figure 2.6: DNA Rearrangements [6]

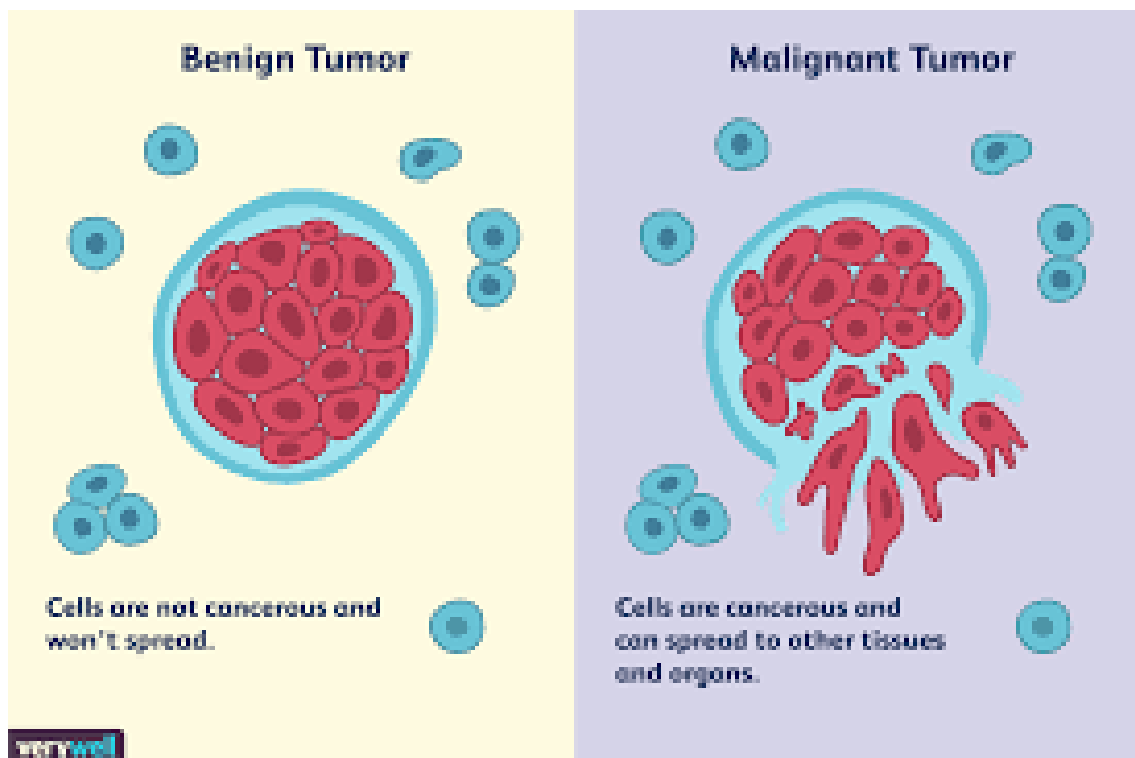


Figure 2.7: Benign and Malignant tumors [7]

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) [18], it is one of the most common cancers in the world [19] 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 ultra violet rays [18] which can come from various sources but the most common are sun light and tanning beds [figure tanning bed] [18–20],,. 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 [20] 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 ultra violet rays provided by the melanin which is present in darker people in more quantities than pale people [20]

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

2.3.2 types

the 3 most common types are the following [18]

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

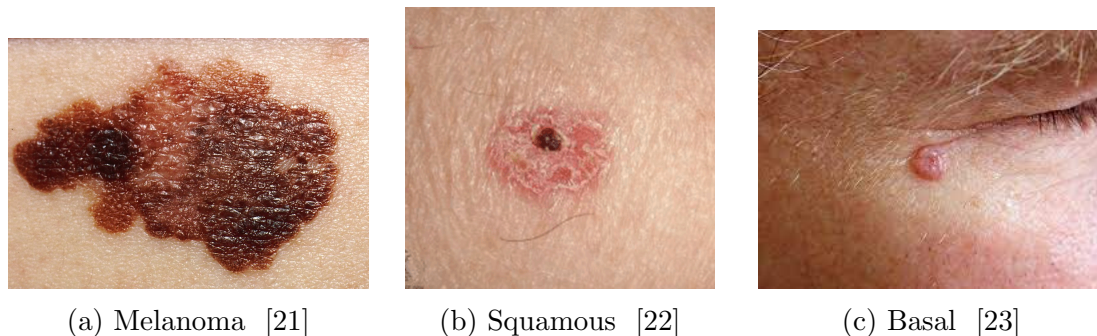


Figure 2.8: 3 Most Common Types of Skin Cancer

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 ultra violet [18–20] radiations that can primarily be found in sun light 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 [20] 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 of generating melanin which is the pigment responsible of the skin color. [20]

2.3.4 risk factors

factors that may increase your chances of getting skin cancer are [20]

Fair skin if you have less melanin which means your skin color is less dark then you are much more likely to get skin cancer then a person with a darker skin because the melanin pigment is responsible of protecting the skin from ultra violet 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 alot or using tanning beds alot is also one of the factors, a tan is your skin's injury response of ultra violet 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 in size than normal moles- can turn cancerous

precancerous skin lesions there are some types of skin lesions -which are in them selfs 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 [20,24]

- 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 treatement

before treatement we need diagnosis first, there are two methods [25] to know that you might have skin cancer. The first method is by observing you 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 determin what stage is it at which is often refered 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) treatement methods may vary depending on the size, type and stage of the cancer [19] but the main way to treat cancer is to remove it completely especially if it is in early or pre-cacerous stages otherwise if additional treatement is needed, the options are as mentioned in [25]:

- freezing with liquid nitrogen
- Mohs surgery which is for difficult cases where the surrounding healthy skin cant 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 cancer 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 [26] to do so Turing has put forward a test called "The Turing Test" which will be explained later, now 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." [26]

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." [27]

3.1.4 the 4 types of Artificial Intelligence

Reactive Machines it is one of the most basic forms 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 specialised set of tasks, this narrowness can be looked at as a limitation but in

fact it is what makes it special in being very trust worthy and error free. a famous example of this type would be the chess playing machine Deep Blue made by IBM in the 1990's which treats each move in the game as it own seperate reality and doesnt rely on past moves [26]

Limited Memory it is a type of artificial intelligence that relies on memory and automatic training , which means learning from past experience to try to make optimised 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 utilise this type [26]: 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 [26].

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 [26].

3.1.5 Artificial Intelligence Categories

generally speaking there are 2 categories of artificial intelligence [26]

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

artificial general intelligence also know as "Strong artificial intelligence", it is the kind of artificial intelligence we see in Science Fiction movies implimented 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 cant accurately explain how he performs face recognition but it is

gained through the experience of observing that face numerous times in different angles and states [28]

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.” [28]

3.2.3 types of machine learning algorithms

there are 3 types [28]

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 optimised 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 then the algorithm is going to cluster the unlabeled data through the structure of the labeled data which offers a huge optimisation 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 take a lot of time also figuring out the connections in the raw unlabeled data.

3.2.4 examples and applications

as mentioned in [28]

Financial Services this industry is using machine learning almost in every aspect, because of its ability to speed up the financial processes and perform 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 individualised 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 along time ago (1950's) but people back then didn't have the computational power to impliment 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 whi made neural networks cool again is Geoffrey Hinton by demonstrating that a few of them could be trained using backprobagation for better shape recognition and word prediction and by 2012 deep learning is basicaly used every where [29].

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." [29]

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 an researchers say it is only a small step in aquiring 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 wont cut it [29].

and there are alot 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 implimented 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 then trial-and-error systems [29]

other ideas that are worth mentioning [29]

ONE-SHOT LEARNING and NAS (neural architecture search) one-shot learning means we need far less 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

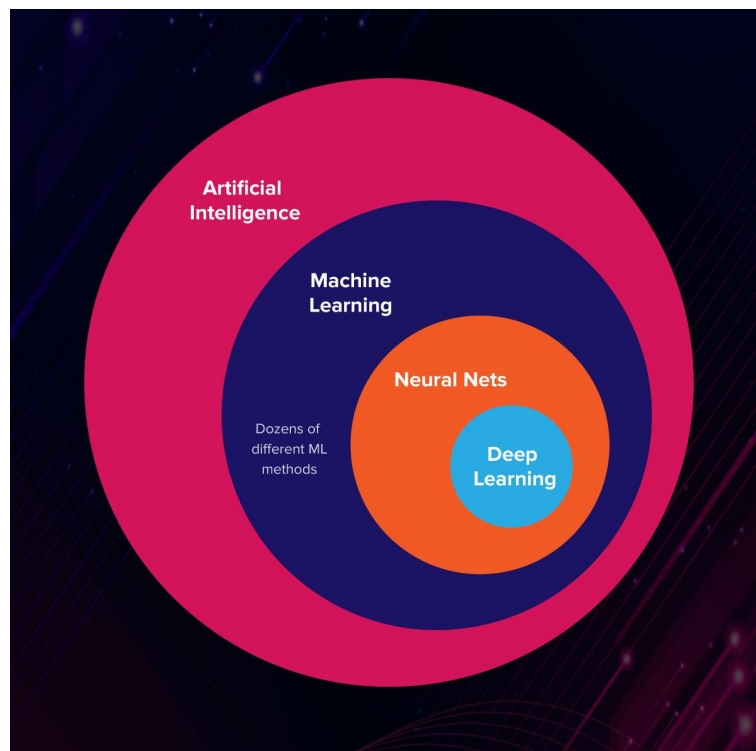


Figure 3.1: AI vs ML vs DL [8]

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 analyse and extract usefull 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, analyse 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 specialised tasks because of there ability to process thousands of images/frames in a short period of time due to the constant increase in computational power especialy (graphical processing). computer vision is used in a wide variety of idustries and its market is estimated to reach 48,6 billion USD by 2022 [30]

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, conversion 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 feeded later to the algorithm, the third step is model training using the prelabeled feature vectors, and the last step is predictions made for new image data, and for this we can chose from a variety of machine learning algorithms depending on our problem: Bayesian Nets, Decision Trees, Nearest Neighbors...etc [9]

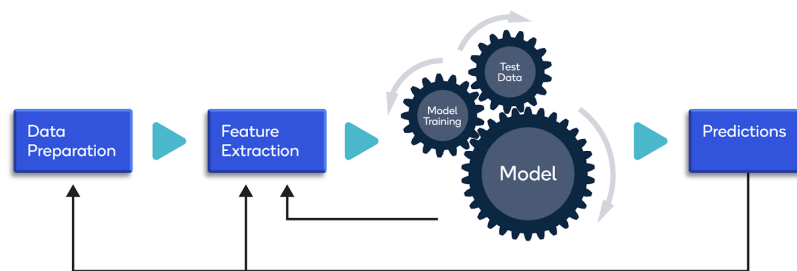


Figure 3.2: Machine Learning in Computer Vision [9]

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 especialy when using Convolution Neural Networks [31](Convolution: a mathematical operation on two functions to produce a third function [30]) this architecture of neural networks is specialised in processing image data and it is built on three primaty layers Convolution layer, pooling layer and fully connected layer [9]

Convolution layer 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 flatened input, where each input is connected to all of the neurons, it is usually found at the and of the network connecting the hidden layers to the output which help in optimizing the class scores

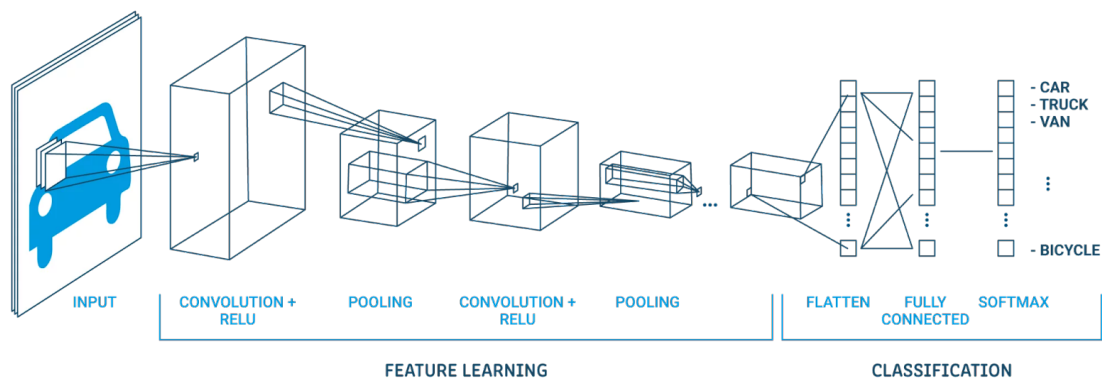


Figure 3.3: Deep Learning in Computer Vision [9]

3.5.4 applications of computer vision

there are alot of indsutries 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 alot of libraries and frameworks that facilitates alot 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

State Of The Art

4.1 Introduction

In this chapter we are going to present some of the recent work and research that was done regarding skin cancer detection and classification using machine learning , we are going to explore the various methods, tools, new ideas and challenges that was handled by researchers for the hope of getting a clear understanding of the problem and how to go about solving it depending on each one's conditions, requirements and goals.

4.2 skin cancer detection and classification using machine learning

proposed methodology the proposed methodology in this article [32] uses a 6 step process (input data - preprocessing - segmentation - feature extraction - classification - output data)

input data dermoscopic images from the ISIC (International Skin Imaging Collaboration) 2019 challenge containing 8 classes of skin cancer, and for simplisity reasons only 800 images out of 25000 is used.

preprocessing because of the heteroginity of the input data a preprocessing step is required to inhance the quality of images and remove irrelevant parts. the main techniques used here are gray scale conversion and the application of the Gaussian and median filter for noise removal and enhancement, and for the unwanted hair they applied the Dull Razor method (a preprocessing algorithm), as shown in figure 4.1

segmentation segmnetation is used to extract the region of interest and for that they used a k-means clustering algorithm as shown in figure 4.2

feature extraction for this they used 2 well know methods, ABCD method and GLCM. ABCD is used in dermatological applications and diagnosis for skin lesions such as melanomas and it is the abreviation of Asymmetry, Border, Color and Diameter. Grey Level Co-occurrence Matrix (GLCM) is used for texture analysis, other features are also used in addition to these 2 methods for further classification such as Autocorrelation, correlation, Standard vector...etc

classification for classification they used MSVM (Multi-class Support vector machine) machine learning algorithm, they used training and testing ratios of 70:30 and obtained an accuracy of 96.25% and the confusion matrix shown in figure 4.3

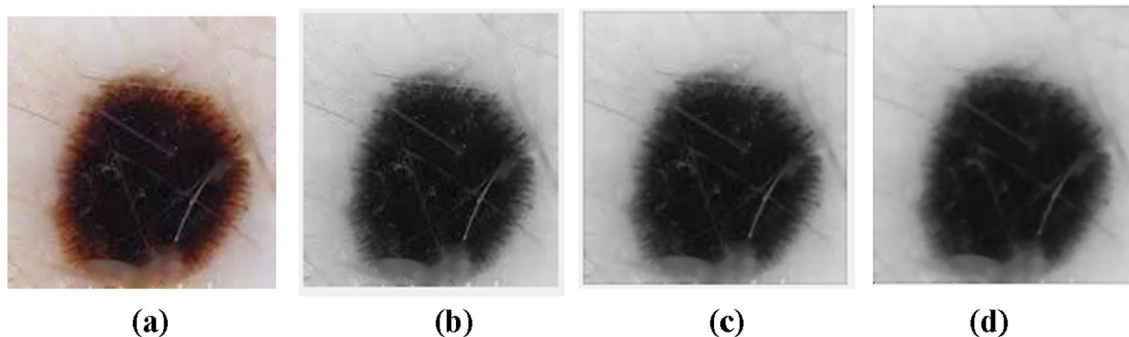


Figure 4.1: Preprocessing: (a) Dull razor image, (b) Gray scale image, (c) Gaussian filter, (d) Median filter.

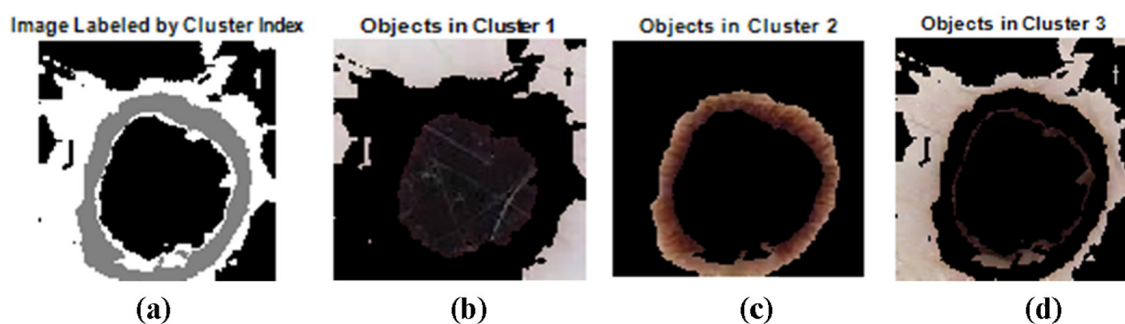


Figure 4.2: Segmentation: (a) Image labelled by cluster index, (b) Objects in cluster 1, (c) Objects in cluster 2, (d) Objects in cluster 3.

4.3 Finding reduced Raman spectroscopy fingerprint of skin samples for melanoma diagnosis through machine learning

This article [33] uses a new non invasive approach to classify malignant and benign tumors, and that is by using Raman spectral data instead of images, Raman Spectroscopy is a way to analyse the chemical structure using light and vibrational energy modes of molecules [34]

data and method

dataset: for the dataset they brought 33 benign and 51 malignant samples and cut them into regular cuts of $2mm^3$, a layer was used to excite the samples to collect the Raman signals using special tools after this they acquired 436 Raman

		Confusion Matrix							
True class	Actinic keratosis	55	2	1	1				1
	Basal cell carcinoma		58			1		1	
	Benign keratosis			60					
	Dermatofibroma	1	2		55			2	
	Melanocytic nevus					60			
	Melanoma					1	59		
	Squamous cell carcinoma			2				58	
	Vascular lesion	1				1		1	57
		Predicted class							
		Actinic keratosis	Basal cell carcinoma	Benign keratosis	Dermatofibroma	Melanocytic nevus	Melanoma	Squamous cell carcinoma	Vascular lesion

Figure 4.3: Confusion Matrix

spectra. and they focused on the biological fingerprint spectral region from 800 to 1800 cm^{-1}

Fluorescence background data pre-process: Fluorescence is a radiation that is emitted by molecules after interacting with electromagnetic radiation and this could overshadow and disturb the study of Raman spectra, to deal with this noise they used a low frequency laser to lower the probability of fluorescence emissions and by this they could jump the preprocessing step.

feature extraction they divided the obtained spectrums into subsequences (local spectrums) and extracted some statistical measures from it such as arithmetic mean, standard deviation, derivative ...etc

results and discussion these statistical features were then given to a machine learning classification algorithm, a complex decision tree implemented using lightGBM (open source software), other algorithms were also used such as K-nearest neighbors and XGBOOST (Extreme Gradient Boosting an open source software) but the best performance was obtained using lightGBM. further research led them to only use the derivative as a feature and a spectral region from 896 to 1039 cm^{-1} because these two were proved the most discriminative information between malignant and benign tumors and by this they obtained a high performant model ($AUC \geq 0.97$) shown in figure 4.4

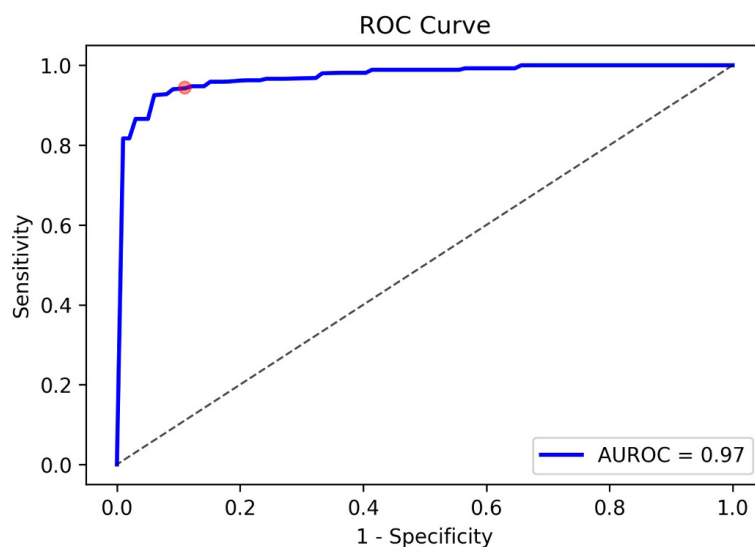


Figure 4.4: ROC

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