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COMPARATIVE STUDY OF MACHINE

LEARNING METHODS USED FOR SKIN

CANCER DETECTION AND CLASSIFICATION

Made by

Khodja Moussa

Balbal Oussama

Supervised by

Dr.Meddah Ishak

A thesis presented for a master’s degree in

Computer Systems Engeneering

Acknowledgement

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Abstract

skin caner is one of the most common cancers in the world and it can be 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 reacent advancements in computational power and in the artificial

intelligence field (especialy its 2 subdomains machine learning and deep learning) C.A.D

(computer aided diagnosis) is considered to be one the best ways for early skin cancer

diagnosis. that is why in this article we are going to do a comparative study of recent

methods and algorithms applied in skin cancer analysis, detection and classification our

comparaison is going to be based of different types of datasets used for trainning , different

algorithms applied and famous performance metrics calculated by researchers such as

accuracy, specificity, AUC (area under curve) ...etc

in the hopes of better understanding

the problem at hand and its applied solutions, and understanding some new explored

ideas and challenges faced by researchers and contributors and finaly this article will help

new researchers to understand what is ahead of them before engaging and contributing

to this field.

many are using machine learning, anyone who is willing to contribute can go through

this article to get a general view on the various applied methods

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Resum´

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Le cancer de la peau est l'un des cancers les plus r´epandus dans le monde et il peut ˆetre mortel s'il n'est pas trait´e tˆot, c'est pourquoi son diagnostic pr´ecoce est consid´er´e comme le meilleur traitement. et a` la lumi`ere des avanc´ees r´ecentes en mati`ere de puissance de calcul et dans le domaine de l'intelligence artificielle (en particulier ses 2 sous-domaines d'apprentissage automatique et d'apprentissage en profondeur), la C.A.D (diagnostic assist´e par ordinateur) est consid´er´ee comme l'un des meilleurs moyens de diagnostic pr´ecoce du cancer de la peau. c'est pourquoi, dans cet article, nous allons faire une ´etude comparative des m´ethodes et algorithmes r´ecents appliqu´es a` l'analyse, a` la d´etection et `a la classification du cancer de la peau. Notre comparaison va ˆetre bas´ee sur diff´erents types d'ensembles de donn´ees utilis´es pour l'entraˆnement, diff´erents algorithmes appliqu´es et performances c´el`ebres. m´etriques calcul´ees par les chercheurs telles que la pr´ecision, la sp´ecificit´e, l'AUC (aire sous la courbe) ... etc dans l'espoir de mieux comprendre le probl`eme a` r´esoudre et ses solutions appliqu´ees, et de comprendre certaines nouvelles id´ees explor´ees et les d´efis auxquels sont confront´es les chercheurs et les contributeurs et enfin cet article aidera les nouveaux chercheurs a` comprendre ce qui les attend avant de s'engager et de contribuer a` ce domaine.

7

General Introduction

...

8

Chapter 1

General Medecal Information

1.1

Skin

The skin is a complex organ a [14], 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 [15]. It represents the largest sensory organ (15% of total body weight and a total area of 1.86 m^2) [16], 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 [17].

1.1.1

Skin Anatomy

The skin is primary composed of 3 main layers as shown in the figure 1.1, each layer has its unique properties and functions [16].

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

1.1.2

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 foucd across the entire body, it provides lubrication, temprerature

regulation and salt and water balance.

there anatomies are shown in the figure 1.2

9

Figure 1.1: Skin Anatomy [1]

Figure 1.2: Hair and Sweat Glands Anatomy [2]

10

1.1.3

Functions of the Skin

The skin has 6 main functions that can be summarized as follows [16]

Protection the skin is a direct interface between the entarnal organs and the environment so it works as a protective barrier against harmful objects and pathogens

(innate/adaptive immunity and unltra-violet light protection [15]) as shown in

figure 1.3

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 indicatings the physical state of the

individual and by showing sign of stress.

Water storage this skin works as a conservative barrier agains water and body fluids

leakage (18-20% of totla body water) as shown in figure 1.3

Synthesis of vitamin D the skin reperesents 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 [15] as shown in figure 1.4

1.2

Cancer

Cancer is an illness caused by the uncontrolled division and spreading of normal cells [18] 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 1.1) and that is because of the ineffectiveness of traditional treatment methods such as hormones, surgery, radiation, and chemotherapy [19]. their ineffectiveness is due to there 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 [20]

1.2.1

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

11

Figure 1.3: Protective/moisture Barrier Functions [3]

Figure 1.4: Hair and Sweat Glands Anatomy [4]

Deaths in 2020

Type

Breast

Lung

Colon and Rectum

Prostate

Skin

Stomach

nealry 10 million

New Cases (millions) in 2020

2.26

2.21

1.93

1.41

1.20

1.09

Table 1.1: Cancer Statistic [11]

12

satisfied these hits are produced by genetic mutations (figure 1.5) or rearrangements

(figure 1.6) that occur over many years and the number of hits necessary is minimal ranging from 3 to 7 only [20]. 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 [18]

Figure 1.5: DNA Mutation [5]

1.2.2

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 [18]

as shown in figure 1.7

malignant tumors fatal if not treated, because they travel to distant places and form other tumors and invade nearby tissue [18] which makes it very hard to remove all its parts, as shown in figure 1.7

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 [18].

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

13

Figure 1.6: DNA Rearrangements [6]

Figure 1.7: Benign and Malignant tumors [7]

14

melanoma formed by melanocytes (cells that make melanin that gives the skin its color)

...etc

1.3

skin cancer

Skin cancer is the abnormal growth of cells found in the epidermis (the outer layer of the skin) [21], it is one of the most common cancers in the world [22] and it falls under the category of a malignant tumor that is formed by fast multiplication of cells wich is caused by mutations/damage in the DNA of those cells, the damage in there DNA is due to the exposure to ultra violet rays [21] which can come from various sources but the most common are sun light and tanning beds [figure tannig bed] [21–23],,. the most common types of skin cancer are basal cell carcinoma, squamous cell carcinoma , melanoma. the

good news is that if it is descovered in an early stage or pre cancurous stage it can be treated easily without leaving a scar

1.3.1

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 neils [23] skin cancer can happen to people of any skin color but it is know that people with darcker skins are less likely to have it because of the protection against ultra violet rays provided by the melanin which present in darcker people in more quantities than pale people [23]

1. Basal cell carcinoma signs and symptoms Figure 1.8c

• bump

• flat brown scar

• bleeding sore that heals and returns

2. Squamous cell carcinoma signs and symptoms Figure 1.8b

• red nodule

• flat lesion with crusted surface

3. Melanoma signs and symptoms Figure 1.8a

• brownish spot

• painful lesion that itches and burns

• dark lesion

1.3.2

types

the 3 most common types are the following [21]

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

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(a) Melanoma [24]

(b) Squamous [25]

(c) Basal [26]

Figure 1.8: 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)

1.3.3

causes

the most common and main cause of skin cancer is the exposure to ultra violet [21–23]

radiations that can primarely be found in sun light and tanning beds, but there are some

cases where the cancer appeard in areas not exposed to the sun like palms, soles, and

under finger neils 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 [23] 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 resposible of the skin color. [23]

1.3.4

risk factors

factors that may increase your chances of getting skin cancer are [23]

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 darcker 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

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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

1.3.5

prevention

as it is mentioned in [23, 27]

• 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

1.3.6

treatement

before treatement we need diagnosis first, there are two methods [28] 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 suspecious 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 [22] but the main way to treate cancer is to remove it completely especialy if it is in early or pre-cacerous stages otherwise if additional treatement is needed, the options are as mentioned in [28]:

• 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)

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• Curettage and electrodesiccation to illiminate 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

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Chapter 2

Artificial Intelligence

2.1

2.1.1

Artificial Intelligence

overview

after breaking the Enigma machine that was made by the Nazies for secure/encrypted communications in world war against the alies, 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 [29] 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 dont always agree on a definition, but we found that the below definition is a good enough explanation.

2.1.2

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.” [29]

2.1.3

turing test

it is basically a test put forward by the mathematician Alan Turing to determin whether a machine is intteligent 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.” [30]

2.1.4

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 spepcialised set of tasks, this narrowness can be looked at as a limitation but in

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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 [29]

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 [29]: 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 throught self reflection [29].

Self-awareness after Theory of Mind is established this is the next step, where machines

bacome self aware and comprehensive of its own existence by obtaining human level

intelligence and consciousness [29].

2.1.5

Artificial Intelligence Categories

generally speaking there are 2 categories of artificial intelligence [29]

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.

2.2

2.2.1

Machine Learning

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 wthout 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 accuratly explain how he preforms face recognition but it is

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gained through the experience of observing that face numerous times in different angles

and states [31]

2.2.2

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.” [31]

2.2.3

types of machine learning algorithms

there are 3 types [31]

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 vary 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 commonaities or lack of commonaities.

Semi-Supervised Learning this types 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 throught 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 usualy done by human beings which means that it takes

alot of time and is bound to human error, and Unsupervised learnning algorithms

takes alot of time also figuring out the connections in the raw unlabeled data.

2.2.4

examples and applications

as mentioned in [31]

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 alot on machine learning because of its ability

to discover new treatements and detect and predict diseases, a medical professional

equiped with machine learning is far more proficient because he can access a patient’s relevant medical history in blink of an eye rather that digging through files

or contacting other departements in the hospital. machine learning is predicted to

save the medical field billions of dollars annualy

Social Media this industry usually uses machine learning for 2 main reasons: strengthening the feel of connection between people and iliminating bad actors, it does the

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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

2.3

2.3.1

Deep Learning

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 didnt'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 [32].

2.3.2

definition

Main source **builtin.com**/.../artificial-intelligence/deep-learning 2%

> "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." [32]

2.3.3

what is next?

although deep learning has brought us many accomplishements

and it can be applied

in various domains and when it is done right it can preform a certain task with superhuman 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 [32].

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 [32]

other ideas that are worth mentioning [32]

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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.

2.4

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 2.1

Figure 2.1: AI vs ML vs DL [8]

2.5

2.5.1

computer vision

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

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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 [33]

2.5.2

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, convertion 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 2.2: Machine Learning in Computer Vision [9]

2.5.3

using deep learning

applying deep learning in computer vision is totaly 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 [34](Convolution: a mathematical operation on two functions to produce a