Automated Iris Recognition using Artificial Neural Networks

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Phase One Requirements:

Topics:

Contents

Phase Two Requirements:

Project idea in details:

Iris recognition is an automated method of biometric identification that uses mathematical pattern-recognition techniques on video images of one or both irises of an individual's eyes, whose complex patterns are unique, stable, and can be seen from some distance. The discriminating powers of all biometric technologies depend on the amount of entropy they can encode and use in matching. Iris recognition is exceptional in this regard, enabling the avoidance of "collisions" (False Matches) even in cross-comparisons across massive populations. Its major limitation is that image acquisition from distances greater than a meter or two, or without cooperation, can be very difficult.

Retinal scanning is a different, ocular-based biometric technology that uses unique patterns on a person's retina blood vessels and is often confused with iris recognition. Iris recognition uses video camera technology with subtle near infrared illumination to acquire images of the detail-rich, intricate structures of the iris which are visible externally. Digital templates encoded from these patterns by mathematical and statistical algorithms allow the identification of an individual or someone pretending to be that individual. Databases of enrolled templates are searched by matcher engines at speeds measured in the millions of templates per second per (single core) CPU, and with remarkably low false match rates.

At least 1.5 billion persons around the world (including 1.2 billion citizens of India, in the UIDAI / Aadhaar programme) have been enrolled in iris recognition systems for national ID, e-government services, benefits distribution, security, and convenience purposes such as passport-free automated border-crossings A key advantage of iris recognition, besides its speed of matching and its extreme resistance to false matches, is the stability of the iris as an internal and protected, yet externally visible organ of the eye.

History:

Although John Daugman developed and patented the first actual algorithms to perform iris recognition, published the first papers about it and gave the first live demonstrations, the concept behind this invention has a much longer history and today it benefits from many other active scientific contributors. In a 1953 clinical textbook, F.H. Adler wrote: "In fact, the markings of the iris are so distinctive that it has been proposed to use photographs as a means of identification, instead of fingerprints." Adler referred to comments by the British ophthalmologist J.H. Doggart, who in 1949 had written that: "Just as every human being has different fingerprints, so does the minute architecture of the iris exhibit variations in every subject examined. [Its features] represent a series of variable factors whose conceivable permutations and combinations are almost infinite." Later in the 1980s, two American ophthalmologists, L. Flom and Aran Safir managed to patent Adler's and Doggart's conjecture that the iris could serve as a human identifier, but they had no actual algorithm or implementation to perform it and so their patent remained conjecture. The roots of this conjecture stretch back even further: in 1892 the Frenchman A. Bertillon had documented nuances in "Tableau de l'iris humain". Divination of all sorts of things based on iris patterns goes back to ancient Egypt, to Chaldea in Babylonia, and to ancient Greece, as documented in stone inscriptions, painted ceramic artefacts, and the writings of Hippocrates. (Iris divination persists today, as "iridology.")

The core theoretical idea in Daugman's algorithms is that the failure of a test of statistical independence can be a very strong basis for pattern recognition, if there is sufficiently high entropy (enough degrees-of-freedom of random variation) among samples from different classes. In 1994 he patented this basis for iris recognition and its underlying computer vision algorithms for image processing, feature extraction, and matching, and published them in a paper. These algorithms became widely licensed through a series of companies: IriScan (a start-up founded by Flom, Safir, and Daugman), Iridian, Sarnoff, Sensar, LG-Iris, Panasonic, Oki, BI2, IrisGuard, Unisys, Sagem, Enschede, Securimetrics and L-1, now owned by French company Morpho.

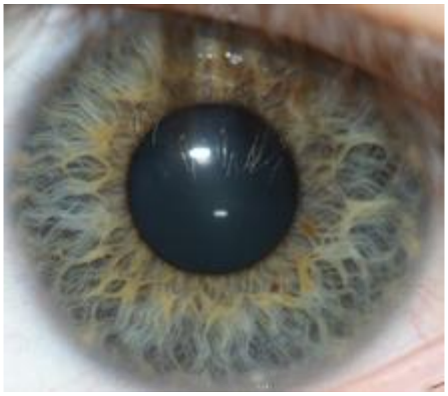
With various improvements over the years, these algorithms remain today the basis of all significant public deployments of iris recognition, and they are consistently top performers in NIST tests (implementations submitted by L-1, MorphoTrust and Morpho, for whom Daugman serves as Chief Scientist for Iris Recognition). But research on many aspects of this technology and on alternative methods has exploded, and today there is a rapidly growing academic literature on optics, photonics, sensors, biology, genetics, ergonomics, interfaces, decision theory, coding, compression, protocol, security, mathematical and hardware aspects of this technology.

Most flagship deployments of these algorithms have been at airports, in lieu of passport presentation, and for security screening using watch-lists. In the early years of this century, major deployments began at Amsterdam's Schiphol Airport and at ten UK airport terminals allowing frequent travellers to present their iris instead of their passport, in a programme called IRIS: Iris Recognition Immigration System. Similar systems exist along the US / Canada border, and many others. In the United Arab Emirates, all 32 air, land, and seaports deploy these algorithms to screen all persons entering the UAE requiring a visa. Because a large watch-list compiled among GCC States is exhaustively searched each time, the number of iris cross-comparisons climbed to 62 trillion in 10 years. The Government of India has enrolled the iris codes (as well as fingerprints) of more than 1.2 billion citizens in the UIDAI (Unique Identification Authority of India) programme for national ID and fraud prevention in entitlements distribution. In a different type of application, iris is one of three biometric identification technologies internationally standardised since 2006 by ICAO for use in e-passports (the other two are fingerprint and face recognition)

Visible vs near infrared imaging:

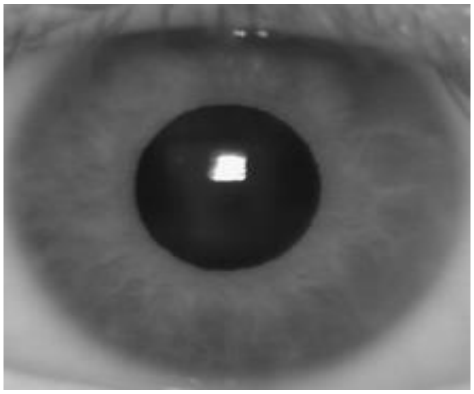
Iris melanin, also known as chromophore, mainly consists of two distinct heterogeneous macromolecules, called eumelanin (brown–black) and pheomelanin (yellow–reddish), whose absorbance at longer wavelengths in the NIR spectrum is negligible. At shorter wavelengths within the VW spectrum, however, these chromophores are excited and can yield rich patterns. Hosseini, et al. provide a comparison between these two imaging modalities. An alternative feature extraction method to encode VW iris images was also introduced, which may offer an alternative approach for multi-modal biometric systems.

Visible wavelength iris image



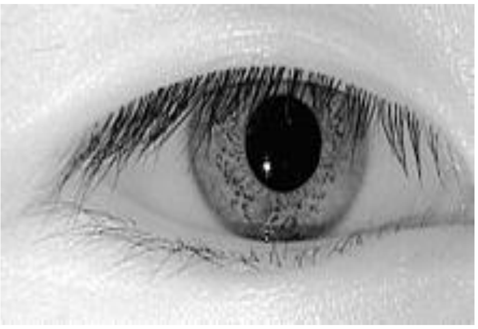
Visible light reveals rich pigmentation details of an Iris by exciting melanin, the main coloring component in the iris

Near infrared (NIR) version



Pigmentation of the iris is invisible at longer wavelengths in the NIR spectrum

NIR imaging extracts structure



Even "dark brown" eyes reveal rich iris texture in the NIR band, and most corneal specular reflections can be blocked

Operating principle:

First the system must localize the inner and outer boundaries of the iris (pupil and limbus) in an image of an eye. Further subroutines detect and exclude eyelids, eyelashes, and specular reflections that often occlude parts of the iris. The set of pixels containing only the iris, normalized by a rubber-sheet model to compensate for pupil dilation or constriction, is then analyzed to extract a bit pattern encoding the information needed to compare two iris images.

In the case of Daugman's algorithms, a Gabor wavelet transform is used. The result is a set of complex numbers that carry local amplitude and phase information about the iris pattern. In Daugman's algorithms, most amplitude information is discarded, and the 2048 bits representing an iris pattern consist of phase information (complex sign bits of the Gabor wavelet projections). Discarding the amplitude information ensures that the template remains largely unaffected by changes in illumination or camera gain, and contributes to the long-term usability of the biometric template.

For identification (one-to-many template matching) or verification (one-to-one template matching),[20] a template created by imaging an iris is compared to stored templates in a database. If the Hamming distance is below the decision threshold, a positive identification has effectively been made because of the statistical extreme improbability that two different persons could agree by chance ("collide") in so many bits, given the high entropy of iris templates.

Advantages:

The iris of the eye has been described as the ideal part of the human body for biometric identification for several reasons:

It is an internal organ that is well protected against damage and wear by a highly transparent and sensitive membrane (the cornea). This distinguishes it from fingerprints, which can be difficult to recognize after years of certain types of manual labor. The iris is mostly flat, and its geometric configuration is only controlled by two complementary muscles (the sphincter pupillae and dilator pupillae) that control the diameter of the pupil. This makes the iris shape far more predictable than, for instance, that of the face.

The iris has a fine texture that—like fingerprints—is determined randomly during embryonic gestation. Like the fingerprint, it is very hard (if not impossible) to prove that the iris is unique. However, there are so many factors that go into the formation of these textures (the iris and fingerprint) that the chance of false matches for either is extremely low. Even genetically identical individuals (and the left and right eyes of the same individual) have completely independent iris textures. An iris scan is similar to taking a photograph and can be performed from about 10 cm to a few meters away. There is no need for the person being identified to touch any equipment that has recently been touched by a stranger, thereby eliminating an objection that has been raised in some cultures against fingerprint scanners, where a finger has to touch a surface, or retinal scanning, where the eye must be brought very close to an eyepiece (like looking into a microscope).

The commercially deployed iris-recognition algorithm, John Daugman's IrisCode, has an unprecedented false match rate (better than 10−11 if a Hamming distance threshold of 0.26 is used, meaning that up to 26% of the bits in two IrisCodes are allowed to disagree due to imaging noise, reflections, etc., while still declaring them to be a match). While there are some medical and surgical procedures that can affect the colour and overall shape of the iris, the fine texture remains remarkably stable over many decades. Some iris identifications have succeeded over a period of about 30 years.

Iris recognition works with clear contact lenses, eyeglasses, and non-mirrored sunglasses. The early Sensar technology worked by first finding the face, then the eyes, and then took the Iris images. This was all done using infrared lighting. It is possible to identify someone uniquely in a dark room while they were wearing sunglasses.

Mathematically, iris recognition based upon the original Daugman patents or other similar or related patents define the strongest biometric in the world. Iris recognition will uniquely identify anyone, and easily discerns between identical twins. If a human can verify the process by which the iris images are obtained (at a customs station, entering or even walking by an embassy, as a desktop 2nd factor for authentication, etc.) or through the use of live eye detection (which varies lighting to trigger slight dilation of the pupil and variations across a quick scan which may take several image snapshots) then the integrity of the identification are extremely high.

Disadvantages:

Many commercial iris scanners can be easily fooled by a high quality image of an iris or face in place of the real thing.The scanners are often tough to adjust and can become bothersome for multiple people of different heights to use in succession. The accuracy of scanners can be affected by changes in lighting. Iris scanners are significantly more expensive than some other forms of biometrics, as well as password and proximity card security systems.

Iris recognition is very difficult to perform at a distance larger than a few meters and if the person to be identified is not cooperating by holding the head still and looking into the camera. However, several academic institutions and biometric vendors are developing products that claim to be able to identify subjects at distances of up to 10 meters ("Standoff Iris" or "Iris at a Distance" as well as Princeton Identity's "Iris on the Move" for persons walking at speeds up to 1 meter/sec).

As with other photographic biometric technologies, iris recognition is susceptible to poor image quality, with associated failure to enroll rates. As with other identification infrastructure (national residents databases, ID cards, etc.), civil rights activists have voiced concerns that iris-recognition technology might help governments to track individuals beyond their will. Researchers have tricked iris scanners using images generated from digital codes of stored irises. Criminals could exploit this flaw to steal the identities of others.

The first study on surgical patients involved modern cataract surgery and showed that it can change iris texture in such a way that iris pattern recognition is no longer feasible or the probability of falsely rejected subjects is increased.

Security considerations:

As with most other biometric identification technology, an important consideration is live-tissue verification. The reliability of any biometric identification depends on ensuring that the signal acquired and compared has actually been recorded from a live body part of the person to be identified and is not a manufactured template. Besides a person's physical characteristics, which includes the eyes, one's voice and handwriting too, are not protected by the Fourth Amendment even though they are all constantly exposed. Many commercially available iris-recognition systems are easily fooled by presenting a high-quality photograph of a face instead of a real face, which makes such devices unsuitable for unsupervised applications, such as door access-control systems. However, this is not the case with all iris recognition algorithms. The problem of live-tissue verification is less of a concern in supervised applications (e.g., immigration control), where a human operator supervises the process of taking the picture.

Methods that have been suggested to provide some defense against the use of fake eyes and irises include changing ambient lighting during the identification (switching on a bright lamp), such that the pupillary reflex can be verified and the iris image be recorded at several different pupil diameters; analyzing the 2D spatial frequency spectrum of the iris image for the peaks caused by the printer dither patterns found on commercially available fake-iris contact lenses; analyzing the temporal frequency spectrum of the image for the peaks caused by computer displays.

Other methods include using spectral analysis instead of merely monochromatic cameras to distinguish iris tissue from other material; observing the characteristic natural movement of an eyeball (measuring nystagmus, tracking eye while text is read, etc.); testing for retinal retroreflection (red-eye effect) or for reflections from the eye's four optical surfaces (front and back of both cornea and lens) to verify their presence, position and shape. Another proposed method is to use 3D imaging (e.g., stereo cameras) to verify the position and shape of the iris relative to other eye features.

A 2004 report by the German Federal Office for Information Security noted that none of the iris-recognition systems commercially available at the time implemented any live-tissue verification technology. Like any pattern-recognition technology, live-tissue verifiers will have their own false-reject probability and will therefore further reduce the overall probability that a legitimate user is accepted by the sensor.

Iris recognition in television and movies:

I Origins (2014), a Hollywood film by writer-director Mike Cahill and winner of the Alfred Sloan Award for best exposition of technology (2014 Sundance Film Festival), uses iris recognition for its core plot. Culminating in India with the UIDAI project to encode and enroll the iris patterns of one billion or more Indian residents by the end of 2015, the film is described as a "science fiction love story incorporating spiritualism and reincarnation", seeking to reconcile science with religious spirit-world beliefs.

Steven Spielberg's 2002 science fiction film Minority Report depicts a society in which what appears to be a form of iris recognition has become daily practice. The principal character undergoes an eye transplant in order to change his identity but continues to use his original eyes to gain access to restricted locations.

In The Island (2005), a clone character played by Ewan McGregor uses his eye to gain access through a security door in the home of his DNA donor.

The Simpsons Movie (2007) features a scene that illustrates the difficulty of image acquisition in iris recognition.

The TV series Numb3rs , features a scene where a robber gets into the CalSci facility by cracking the code assigned to a specific iris.

NCIS uses an iris scanner in the garage, where forensic vehicle investigations are carried out and evidence is stored. There is another scanner at the entrance to MTAC. The sequence of Leroy Jethro Gibbs being verified is shown in the title sequence. The imagery for this sequence has been "enhanced" using special effects. Iris recognition systems do not use the laser like beams shown in the sequence and the light that they do use is near-infrared and nearly invisible.

The 2010 film Red includes a scene where Bruce Willis' character uses a contact lens to pass an iris scan and gain access to CIA headquarters.

The film "Angels and Demons" and the book featured an iris scanner as the method by which the protagonist broke into CERN and stole one of the antimatter storage modules.

The film "Demolition Man" also had a scene where an eyeball on a stick was used to break into a weapons storage facility.

Main Functionalities :

The iris has a fine texture that—like fingerprints—is determined randomly during embryonic gestation. Like the fingerprint, it is very hard (if not impossible) to prove that the iris is unique. However, there are so many factors that go into the formation of these textures (the iris and fingerprint) that the chance of false matches for either is extremely low. Even genetically identical individuals (and the left and right eyes of the same individual) have completely independent iris textures. An iris scan is similar to taking a photograph and can be performed from about 10 cm to a few meters away. There is no need for the person being identified to touch any equipment that has recently been touched by a stranger, thereby eliminating an objection that has been raised in some cultures against fingerprint scanners, where a finger has to touch a surface, or retinal scanning, where the eye must be brought very close to an eyepiece (like looking into a microscope).

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Immigration Control

In response to the increasing threats of terrorism around the world, NEC contributes to a safe and secure society by enhancing stringency of immigration control. Our iris recognition solution offers improved security and smooth personal identification amidst the increasing movement of people between countries.

Crime Investigation

A multimodal biometrics database for managing multiple biometric authentication data is created by taking images of the face, fingerprint, and palm print, as well as the iris. Combining with fingerprint and other biometric authentication systems enables more accurate identification of an individual.

Combined use of biometric data allows recognition even when the fingerprint, for example, could not be used for identification due to injury.

National ID

NEC promotes equal access to administrative services by providing legal identification for all citizens. By enhancing security of national ID systems, our solution contributes to realizing more advanced national identification services.

Iris recognition is used as one of the methods for acquiring biometric data needed for issuing unique IDs.

Accurate and fast authentication is possible even without an ID card.

Combined use with mutually complementary biometric data, such as fingerprint and face, enables rigid personal authentication and a robust approach against impersonation.

In addition to National ID, the solution is suitable for passports, driver's licenses, and voter ID systems.

Iris image quality determination. The image quality estimation can be used during iris enrollment to ensure that only the best quality iris template will be stored into database. Roll angle can be determined from iris image for further decisions about accepting the image for enrollment. Also, irises, which are obscured by cosmetic (decorative) contact lenses with some artistic images or color change, can be rejected from enrollment.

Liveness detection. A captured iris can be analyzed whether it is "live" or a spoof to prevent security breach performed by placing a photo in front of the camera or wearing contact lenses with fake iris texture.

Automatic iris position detection. The algorithm is able to separate images of left and right irises.

Accuracy: Iris recognition is one of the best biometric modalities in terms of accuracy. The false acceptance rate and false rejection rate is very low in this modality, thus ensuring a higher rate of accuracy in its results.

Scalability: This technology is highly scalable and can be used in both large and small scale programs. It has been deployed in many large scale programs including the respective government's biometric authentication programs in several countries across the world.

Distance: Unlike retina scanning, iris scanning can be done from a normal distance. It is like taking a normal photo, which can be taken from the regular distance of taking pictures.

Stable: Iris patterns remain stable throughout an individual's life. It is protected by the body's own mechanism.

Easy to use: Iris recognition system is plug & play compared to other modalities of biometric recognition. A person needs to stand still in front of the camera and the job is done instantly. It is a comfortable process for everyone

Fast: With iris recognition system, a person can complete the process within just a few seconds. If the initial enrollment has taken place, it works faster than other modalities. From next enrolment, a camera will capture the iris, and then the matching system will work with the database and send the report instantly.

Non-intrusive: A person doesn't need physical contact with the devices to perform an iris scan. As there is no direct physical contact between the subject and camera, this technology is not intrusive at all.

Non-invasive: Iris recognition can be done with simple video technology. No use of laser technology is necessary to scan the iris making it a non-invasive technology altogether.

Hard to forge: The whole iris recognition system is difficult to forge by any means, making it simple and secure. This biometric modality is deployed in a lot of countries, but there are hardly any data breach records of this modality.

Engagement: It needs the subject's engagement to perform a iris recognition scan. The scanning camera can't record an iris without the subject's proper engagement at some point of the process.

Glass/Contact lenses: A lot of people use glass or contact lenses to see things perfectly. Though these gadgets are very close to the eye, it doesn't make any difference in the iris recognition process.

Randomness: The randomness degree of iris pattern is very high which makes every iris unique. As an example, the variability iris has 244 degrees-of-freedom and the entropy has 3.2 bits per square-millimeter.

Pupil size : The changing pupil size confirms the natural physiology of an iris. But, the pattern of an iris doesn't change.

Protection: The iris is an internal organ of the eye. For this reason, iris pattern never changes in a lifetime. As an internal organ, it is highly protective compared to retina recognition.

Traceable: The encoding and decision making of iris pattern is highly traceable. It takes only 30 milliseconds for the image analysis and the subsequent encoding.

Similar Applications in the market :

1. United Arab Emirates IrisGuard's Homeland Security Border Control has been operating an expellee tracking system in the United Arab Emirates (UAE) since 2003, when the UAE launched a national border-crossing security initiative. Today, all of the UAE's land, air and seaports of entry are equipped with systems. All foreign nationals who need a visit visa to enter the UAE are now processed through iris cameras installed at all primary and auxiliary immigration inspection points.

2. Bank United - Texas. In 1999 Bank United became the first bank in the world to deploy iris recognition ATMs. These ATMs were manufactured by Diebold using iris recognition technology.

3. Hashemite Kingdom of Jordan - 2009, IrisGuard deployed one of the world's first operational iris-enabled automated teller machine at Cairo Amman Bank, where bank customers can seamlessly withdraw cash from ATM's without a bank card or pin but simply by presenting their eye to the iris recognition camera on the ATM.

4. Police forces across America planned to start using BI2 Technologies' mobile MORIS (Mobile Offender Recognition and Information System) in 2012. The New York City Police Department was the first, with a system installed in Manhattan in the fall of 2010.

5. Canadian Air Transport Security Authority's Restricted Area Identity Card (RAIC) program is the world's first dual-biometric program deployed around major Canadian airports for staff and aircrews to access the restricted areas using separate channels from passengers

6. Since at least 2011, Google uses iris scanners to control access to their datacentres.

7. On May 10, 2011, Hoyos Group demonstrated a device called EyeLock using iris-recognition as an alternative to passwords to log people into password-protected Web sites and applications, like Facebook or eBay.

8. On May 28, 2015, Fujitsu released ARROWS NX F-04G the first smartphone with an iris scanner

9. On mid 2015, the Kenya Ministry of Education, Science and Technology in order to provide an accurate attendance tracking for all students in classes (roll-call) or school buses (getting on/off tracking) has implemented iris biometric system. The solution includes IriTech’s IriShield camera connecting to a low cost Android phone or tablet via USB cable. Iris matching is done on-board of IriShield whose internal gallery can hold up to 500 identities (expandable to 5,000 identities) which is more than enough for most of the schools. The local matching capability is a particular advantage in the school-bus scenario because it does not require wireless/3G communication between the biometric terminal in the bus and a back-end server.

10. At the end of 2015, Microsoft launched two Lumia phones (Lumia 950 and Lumia 950 XL) featuring iris scanning as a way to authenticate the user.

11. May 1, 2017, the first iris-enabled humanitarian blockchain system in the world was deployed in Azraq

Refugee camp in Jordan by IrisGuard. More than 10,000 Syrian refugees use only their eyes without any token to pay for their food on WFP Building Blocks (a Private Ethereum Blockchain on AWS) to redeem their assistance

Initial literature review of Academic publications relevant to idea :

A Review of Literature on Iris Recognition

Article *in* International Journal of Research · February 2020

DOI: 10.32968/1632-2882

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A Review of Literature on Iris Recognition

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***Abstract*—This paper presents a survey of literature related to the one of the biometric recognition systems - iris recognition system. Biometric authentication has become one of the important security technologies due to the prominent properties of biometrics compared to other authentication methods. Since most of the phenotypes of humans are unique, physiological traits like fingerprints, iris color, face patterns and geometries considered as security passwords. Among those, iris gets the most attention in authentication because of it is reliability. Even the iris textures which will be used in iris recognition are not similar in the left and right eyes of the same person making iris recognition more secure than popular face recognition. The aim of this paper isto explore recent developments in iris recognition systems and algorithms behind them.**

***Index Terms*—iris recognition, biometrics authentication, im- age processing, machine learning**

I. Introduction

Iris recognition is one of the emerging areas in security and have received more attention in recent years. One of the recent challenges of this biometric authentication was on how to apply biometric security solutions when biological characteristics of humans are rapidly changing. This was a considerable problem and had to adopt numerous mathematical and machine learning models to predict such characteristics in advanced to perform better authentication. But one of the unusual feature of iris is that it is stable in person's life span [1]. This makes iris recognition to become more popular in security industry.

Iris is a thin, circular structure in the eye, which is responsible for controlling the size of the pupil. It mainly consists of few components as Fig.1 shows.

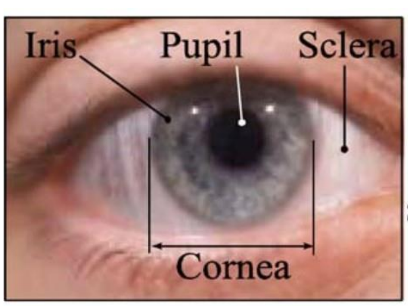


Fig. 1. The anatomy of eye

Cornea is the transparent front part of the eye that covers the iris, pupil, and anterior chamber which is the aqueous humor- filled space inside the eye where iris is pigmented muscular curtain which consists of the unique patterns. Since Cornea is not a barrier to iris scanning, automated machines can clearly read iris patterns and use step by step mechanism to extract features for authentication purposes.

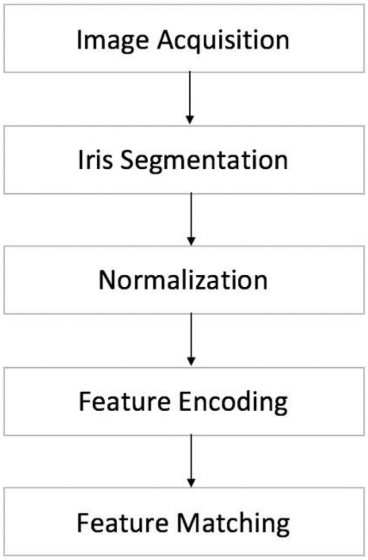


Fig. 2. Iris Recognition Process

As shown in Fig.2, Iris image acquisition stage captures rich detailed image of unique structure of iris using sophisticated technology while illuminating eye by near infrared wavelength light because that reveals rich information even in darker irises [2]. After obtaining the image, pre-processing of image will carried out to do edge detection, adjustments of contrastof the image. Then use mathematical and statistical modelsto identify the part of iris in image and this process callsiris Segmentation. Next stage, normalization transform theiris image from Cartesian coordinates to Polar coordinates in order to allow comparisons [2]. All the other problems likelow contrast can be corrected using image enhancement algo-rithms. Then in feature extraction process, extract bit patterns containing the information/features to identify whether two feature templates are matching. It may use texture analysis method to extract such features. Extracted information will be stored as feature templates for matching purposes in a database. In comparison if the distant calculation is below than the threshold value, decision with higher confident level will be considered. Databases which consist of image templates will be used by image matching engines to carry out millions feature templates per second comparison speed with nearly zero false matching rates [2].

In this paper, each stage of the iris recognition will be discussed separately to thoroughly identify issues of proposed methods and compare them to find how researchers have adopted different technologies to address ongoing problems.

II. Related work

In related work, most of the current iris recognition systems and their algorithms will be covered.

A. *Image Acquisition*

Iris image will be captured with highly sensitive equipment. Thus, it will guarantee the quality of captured image. This phase is mere an image capture. But it is necessary to ensure that the method can overcome obstacles that frequently find in acquisition process which are blurry images,camera diffusion,noise,light reflection and other things which may affects the segmentation process [3].

B. *Image Segmentation*

Iris recognition algorithm starts to work from this phase onward. Segmentation approximate the iris by two circles.One circle approximates iris boundary and second circle approximates pupil boundary. Level of success of segmentation depends on the quality of the image that camera acquires. If the camera was sophisticated iris scanning camera which uses NIR (Near Infrared) wavelengths to capture iris image will have less disturbances like specular reflections. But if it has captured the image under natural light, there will be specular reflections and affect to have less features. Also, some people have darkly pigmented irises and will be much harder to separately identify iris region and pupil region because of the low contrast. [4] Before capturing the iris with approximated bounds, iris should be localized. There are plenty of methods

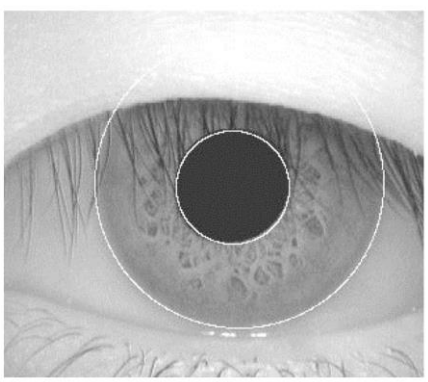


Fig. 3. Iris Localization

being used for this particular function and most popular ones are listed and discussed below.

1) Hough Transform: One of famous computer vision algorithms which uses to identify different kind of shapes in an image such as squares, circles. Since iris segmentation deals with identifying two circular objects in 2D image, more specifically Circular Hough transformation can be adopted [5]. First edge detector should be applied to the image which already has been converted to grey scale and calculate first derivatives of the intensities of the image with thresholding result to make the edge map. After, “voting procedure” will be carried out to cast votes to Hough Space. These votes will be used as the parameters of the circle which passing through each edge point [5].

$$x_c^2 + y_c^n - r^2 = 0 \qquad (1)$$

Parameters x_c and y_c in Equation 1 denotes center coordinates and r is the radius. Maximum Center coordinates with radius define as the best fitted contour. Since this detection still having the disturbance of eyelids, wildes et al. [6] uses two edge maps. Horizontal edge map for detection of eyelids and vertical edge map for detecting iris boundary. Reasonbehind obtaining such bias derivatives for horizontal edge map to detect eyelids is, eyelids are normally in the horizontal direction. If horizontal edge map used to identify iris boundary, there will be an effect from eyelids. So, vertical edge map will be used for iris boundary identification to reduce the influence of eyelids.

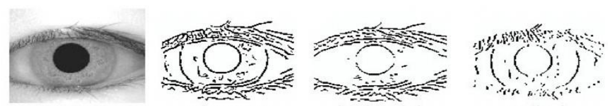


Fig. 4. Original image of eye and different edge maps

Even though Hough Transform is a popular method,still it has disadvantages. It is not suitable for real time applications since it’s requirement of computational power is high. Also, Hough transform needs to generate a threshold value to filter results. Calculation of threshold value and its selection may cut off required points in the edge map and will lead to false circle identification.

2) Dougman’s Algorithm: In Dougman’s algorithm, it uses integro-differential Operator to successfully approximate inner and outer boundaries of iris and upper and lower eyelids [2].

$$\max_{(r,x_0,y_0)} \left| G_\sigma(r) * \frac{\partial}{\partial r} \oint_{(r,x_0,y_0)} \frac{I(x,y)}{2\pi r} ds \right| \qquad (2)$$

Here I (x, y) is the intensity of eye image's x and y coordinates, r defines as the radius, Gaussian smoothing function also will be used here as function of G, s denotes the contour of the circle given by radius [2]. This operator starts from one point and will calculate partial derivatives of intensities of the circles which are having variable radius. So, it tries to find the global minimum in the image. After using the Gaussian function, can identify the positions of inner and outer circles using minimum difference and also the radius. Since this still have a problem with eyelids occlusion, it uses modification to transform circular to parabolic detection. That will identify the iris part more accurately.

Dougman's Algorithm is less computationally intensive than Hough transform because it uses first derivative and no requirement of calculating threshold value. Thus this still uses for commercial grade security systems.

3) Canny and Sobel edge detection : In [7], both Canny and Sobel edge detection will be considerd and select which will perform better. First in Sobel edge detection, an operator will be selected for each point of the given iris image and it will generate the corresponding gradient vector. This operator uses two 3x3 matrix kernels which are convolved with the original image to calculate the approximations of the derivatives [7]. However, if A is considered as the source image which means the iris image, W_x and W_y has to be defined as images which contain horizontal and vertical derivatives ofthe approximations.

$$W_x = \begin{bmatrix} +1 & 0 & -1 \\ +2 & 0 & -2 \\ +1 & 0 & -1 \end{bmatrix} * A \tag{3}$$

$$W_y = \begin{bmatrix} +1 & +2 & +1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} * A \tag{4}$$

* denotes 2-dimensional convolution operation.

Unlike Sobel, Canny edge detection has several steps. Which are smoothing,finding gradient,non-maximum sup- pression, thresholding and determine respectively. In first step,noise of the image will be removed by blurring the iris image. Then after operator is identifying the large magnitude of gradient of image, it marks edges. After completion of pre- vious step, operator will mark local maxima as edges. Before determine edges, thresholding will be used to identify strongestedges and determination stage will remove weak edges which are not connected to any strong ones.As researcher explains in [7], Canny operator is optimum even for noisy images and hasbetter performance than Sobel. But Sobel has the advantageof detect both horizontal and vertical edges separately. Which makes Sobel relatively more cost effective than Canny.

4) Eyelids and eyelashes detection: Eyelids and eyelashes are noise factors in eye image and may cover iris region. There are several methods to detect eyelids and eyelashes including methods we discussed earlier. However in [8],researchers are proposing a new method of using histogram equalization (HE) and adaptive equalization histogram (AHE) before carrying out image segmentation. By using HE in acquired image, it may increase the overall contrast of given image by distributing the intensity values. Thus, it will introduce a problem which is that contrast enhancement will affect the overall brightness. This ultimately may result in low/excessive saturation in some parts of the image. To overcome that issue, AHE will be used and it

will help Canny operator to efficiently identify iris neglecting noises. In [10] also canny operator has been used for edge detection. As this researcher highlights, canny technique is nearly perfect and robust compared to other mechanisms. First it blurs out the image to smooth the image and remove noise came from the camera. For that, Gaussian filter will use there. Then to find the edge where intensity is high, Sobel operator will be used since Sobel operator is very powerful to find gradient of an image. After getting the gradient, blurred edges will convert to sharp ones and using threshold value, potential/strong edges can be determined [10]. By using BLOB (Binary Large Object) analysis, strong edges will be selected as final edges. Finally, linear Hough transform will use to identify noise factors such as eyelids and lashes and Circular Hough transform will detect iris region like in Fig 5.

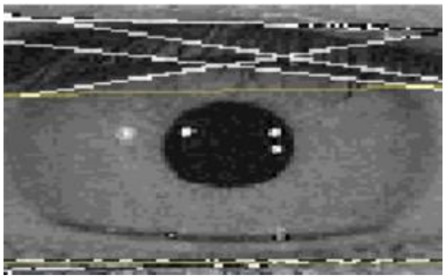


Fig. 5. Result after removal of eyelids and lashes from original image [10]

will increase contrast locally or in certain places. This is basedon equalization of histograms from smaller areas [9]. This

5) Fuzzified Image Enhancement: Rather than proposing a new method for segmentation, this researcher propose a new image enhancement mechanism which will help to segmentthe iris accurately even with occlusions. Since Fuzzy Image enhancement works without deep learning and performance better than traditional methods in image processing, [11] seeks to find a new approach combing fuzzy image enhancement with deep learning and use it to correctly identify iris in segmentation phase.

This method will initiate by enhancing the features of iris image. Thus will help to efficiently identify iris and pupil regions. Applying fuzzy image filters at the end will blur non- relevant parts of the image. Triangular Fuzzy Average Filter, Triangular Fuzzy Median Filter and Gaussian Filter will be used to smooth noise and enhance edges after well-known Hough Transform detects the iris. [11].

In the Convolutional Neural Network phase, they use typical architecture of CNN and train it to extract the features and parallelly train a Capsule network (CN) for the same purpose. Fig. 6 and Fig. 7 shows theirs architectures respectively. This researcher has trained all together four networks which are CNN, F-CNN, Capsule Network and F-Capsule. F-CNN and F-Capsule refer to CNN and Capsule Network training onfuzzified images.

6) Deep learning based iris segmentation: Another inter- esting research has been conducted by M.Trokielewicz et al.

[12] which is about using deep-learning based iris segmenta- tion in post-mortem. This topic was initially proposed backin 2015 and since then researchers were working hard on

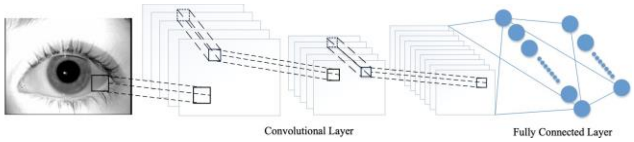


Fig. 6. Proposed CNN in [11]

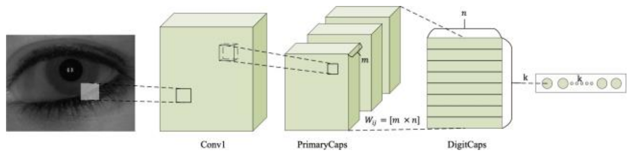


Fig. 7. Proposed Capsule Network in [11]

deceased subject's iris evaluation. However M.Trokielewicz et al. claims their proposing method is promising even than algorithms use in commercial products and trying to develop a drop-in replacement for the Daugman method recognition pipeline [12].

Initiation happens with data-driven segmentation model based on a deep convolutional neural network which usesto localize the iris image and this model has been trainedwith standard methods of machine learning such as cross validation with training images to minimize the over-fitting. As researcher already mentioned, to make this method a drop-in replacement, normalization should be carried out efficientlyand accurately. Thus, segmentation has to be correctly nor- malized onto a dimensionless polar-coordinate rectangle [12]. To tackle this issue, they have followed the same procedure introduced by H.Hofbauer et al. in [13] research. They have introduced a method which will to parameterize segmentation carryout by a CNN model and bridging the gap between CNN based segmentation and the rubbersheet-transform. So, after this masking process, rubbersheet-transform can be directly used for the normalization.

7) Results: In the Segmentation stage, automation iris segmentation proved to be successful [4]. L.Masek et al. [4] have taken two iris databases CASIA and LEI and iris segmentation algorithms managed to segment iris and pupil regions success rate of 82% and 62% respectively. Still there were problematic images in the database which having little intensity differences between pupil boundary and iris boundary causes to wrongly identify them. In Fig 8, this intensity difference leads canny

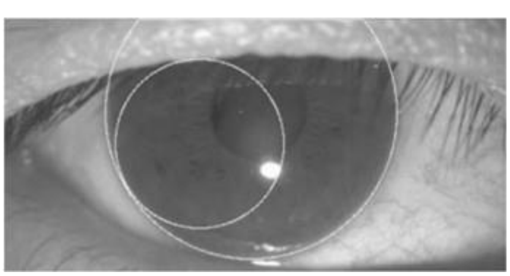


Fig. 8. There is a white point in iris boundary [4]

edge detection method to falsely identify edges. So, researcherexplains that proper parameter setup can remove these prob- lems.

In [11], researcher has show that their fuzzified images with deep learning capsule network has achieved best results compared to other methods according to Fig.9. As in practical applications, it is difficult to capture iris when glasses at pres- ence and because of various lighting conditions, etc. Applyingthe fuzzified image enhancement can help the training process and training outcome (accuracy), and ultimately better adapt.

OVERALL PERFORMANCE OF PROPOSED MODELS

		CNN		F-CNN		Capsule		F-Capsule	
	Sample Number	Accuracy	Iteration/Time(s)	Accuracy/ (ANOVA)	Iteration/Time(s)	Accuracy	Iteration/Time(s)	Accuracy/ (ANOVA)	Iteration/Time(s)
CASIA	20,000	72.9	423/50,183	75.4/(.024)	307/35,147	81.4	312/16751	**83.1/(.016)**	**189/12890**
Cogent	1163	82.8	1876/11,786	**86.8/(.040)**	1315/8,301	80.2	175/591	83.3/(.043)	**98/334**
Vista	1000	83.2	1682/11,474	86.2/(.013)	1107/7,568	85.4	158/521	**88.4/(.013)**	**81/264**
ATVS	800	82.8	853/743	85.8/(.040)	672/548	84.4	439/2344	**89.2/(.003)**	**240/1289**

Fig. 9. Results of [11]

Unlike other research proposals, [12] has completely took the advantage of prominent features of Convolutional Neural Networks to accurately and efficiently do the segmentation process. According to Fig. 10, proposed method has shown lower EER rate than other algorithms even being used incommercial products such as IriCore.

Data subset	**original OSIRIS** [%]	**IriCore** [%]	**proposed** [%]	number of comparisons
$\leq$ 10h postmortem	16.89	5.37	**0.96**	46 360
$\leq$ 24h postmortem	18.73	6.31	**1.36**	61 425
$\leq$ 48h postmortem	20.34	8.00	**3.38**	88 831
$\leq$ 60h postmortem	23.69	10.46	**7.18**	178 503
$\leq$ 110h postmortem	24.72	14.36	**10.36**	296 065
$\leq$ 160h postmortem	28.68	17.79	**15.02**	405 450
$\leq$ 210h postmortem	29.94	20.77	**17.60**	476 776
$\leq$ 369h postmortem	33.59	25.38	**21.95**	597 871
disease data	8.90	3.97	**2.55**	152 076

Fig. 10. Comparison results of [12]

C. Image Normalization

When capturing the image from camera there can be various factors affected. The distance to the eye from camera will not be unique every time. So, that may affect the size of the pupil and the iris image. That will cause texture deformation of the iris and can be lead to poor performance in feature extraction and feature matching stages. Also, rotation of eyes, rotationof camera may lead to such problems as well. Due to these various factors iris has to be normalized to compensate.

1) Dougman's Rubber Sheet Model: A model that proposedby John Daugman remaps pixels in iris region from Cartesian coordinates to Polar coordinates [2]. It uses polar coordinates where is the angle from 0 to 2 and r is the radius which changes from 0 to 1.

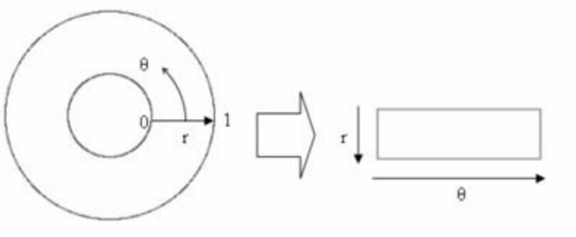


Fig. 11. Rubber sheet model mapping

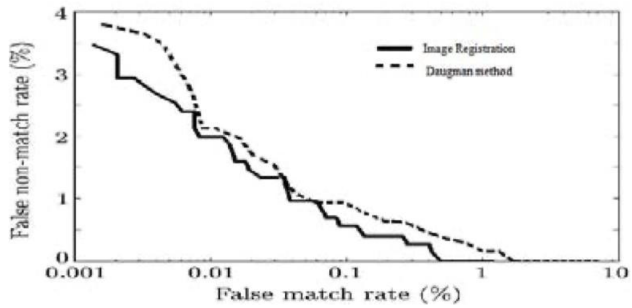


Fig. 12. Verification results of Image registration and Rubber Sheet method [14]

$$I(x(r,\vartheta), y(r,\vartheta)) \rightarrow I(r,\vartheta)$$
where
$$x(r,\vartheta) = (1-r)x_p(\vartheta) + rx_l(\vartheta)$$
$$y(r,\vartheta) = (1-r)y_p(\vartheta) + ry_l(\vartheta) \quad (5)$$

feature extraction stage. To avoid these factors normalized image must be enhanced using different techniques to com-pensate.

This remap of iris region can be modelled using Equation.5 where (x, y) are Cartesian coordinates of iris image, and are Cartesian coordinates of pupil boundary along direction and iris boundary along direction. In this method iris region canbe mapped to a single plane sheet to allow comparisons. Also, have to note that this rubber sheet model does not compensate for rotation variance but for pupil dilation, image distance inconsistencies and non-centric pupil displacements. In the normalized iris image as in Fig. 11, r's direction willcall as radial direction and direction of as angular direction. Still almost all researches use rubber-sheet model for iris normalization. But there are other researches carried out to find new mechanisms.

2) *Image Registration technique:* In [14], researcher in-troduces a new method to transform the iris texture fromcartesian to polar coordinates also known as iris unwrapping. This method has four steps which are Feature detection, Feature matching, Transform model estimation and Image re- sampling and transformation. Initially, a mapping function hasto be selected.Thus method initiate by geometrically wrappingsegmented image $I_a(x,y)$ into alignment with a image picked from the database $I_d(x,y)$. Mapping function (u(x,y),v(x,y)) which uses to convert original to the polar coordinates hasto be selected by minimizing the Equation.6.

$$\int\int (I_d(x,y) - I(x-u, y-v))^2 dxdy \quad (6)$$

Secondly, Phase Correlation Method will be introduced which is based on Fourier shift property. Thus this will generate linear phase differences by transforming a shift in thecoordinate frames of two functions. However using these two methods and according to Image Registration technique steps, researcher proves their method is even better than Dougman's Rubber Sheet Model.

Phase correlation method efficiency results in Fig. 12 proveresearchers claim.

3) *Image Enhancement:* Low contrast of the image as well as non-uniform illumination may cause poor performance in

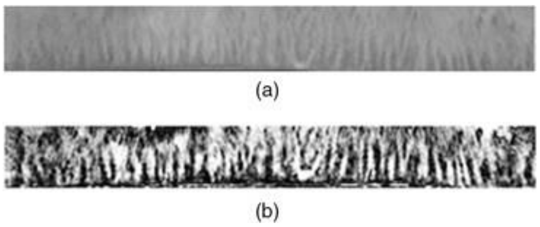


Fig. 13. (a) Before Enhancement (b) after enhancement

One of the techniques is using Local histogram analysis which make uniformly illumination image with rich detailed normalized image [15], [16]. Before enhancing the image Fig.13 (a) details can identify poorly. But after enhancement, rich details of the image are visible to do a better feature extraction. But still there can be issues because of reflections. These can be removed by simple thresholding operation as
[17] explains.

4) Results: Even new researchers are using Dougman's Rubber Sheet Model for normalization and it is also a widely accepted method in industry as well. Anyway new method Image Registration technique [14] has proved that their methodis efficient than Dougman's method. However, normalization process address problems of pupil dilation but may not be accurate all the time because pupil dilation may influenceperfectly reconstructs surface patterns. So still researches can be conducted in this area to make this process more robust.

D. Feature Extraction

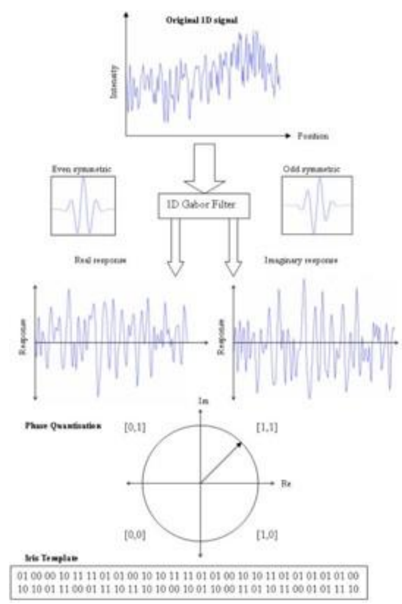
Feature extraction is the next stage where unique featuresof normalized image will be extracted and store as biometric template. There only significant features should be encoded to make a proper comparison with higher confidence between two templates. When it comes to compare two templates, there are main two comparison classes. Comparing two templates which made from different irises come under inter-class comparisons and there should provide one range of values. When comparing two templates from same iris, called intra-class comparison should provide different range of values [4].

1) Laplacian of Gaussian Filters: The Laplacian is a two dimensional isotropic estimation of image's second spatial derivative [18] and it also can be employed to extract information from normalized iris image by decomposing iris region [19].

$$\nabla G = \frac{1}{\pi\sigma^4} \; 1 - \frac{\rho^2}{2\sigma^2} \; e^{-\rho^2/2\sigma^2} \qquad (7)$$

is the radial distance and denotes standard deviation of Gaussian [4]. Using Equation.7 ,generated image call as *Laplace Pyramid*. Laplace pyramid is also constructed using 4 levels and will be used to generate iris template.

2) Gabor filters: In [2], Daugman uses 2D Gabor filterto extract features from normalized image. Gabor filter is constructed using sine and cosine waves with Gaussian. This method is used to optimally combine localization of space and frequency. Here sine wave is optimally localized in frequency and poorly localized in space. So, sine modulation with Gaussian provides localization in space. This filter has real and imaginary components to represent orthogonal components also knows as even symmetric and odd symmetric respectively.



Daugman uses 2D Gabor filter in image domain (x, y) as in Equation.9 to extract features.

$$G(x, y) = e^{-\pi[(x-x_0)^2/\alpha^2 + (y-y_0)^2/\beta^2]} e^{-2\pi i[u_0(x-x_0)+v_0(y-y_0)]} \quad (8)$$

Here (u_0,v_0) denotes modulation and partial frequency defines in Gabor filter denotes by,

$$\omega_0 = \sqrt{u_0^2 + v_0^2} \quad (9)$$

(x_0,y_0) denotes the location in the image and denotes effective width and length [4].

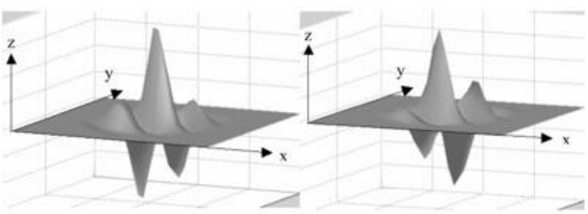


Fig. 14. Odd Symmetric 2D Gabor filter on the left and even Symmetric Gabor filter on the right [4]

Each pattern separates to extract its information use these two Gabor filters. As shown in Fig.15, 2D iris pattern is divided into several 1D signals and then 1D signal convolve with 1D Gabor filter to get the response. Using Odd and even symmetric Gabor filters can obtain real response and imaginary response and then this phase information quantifies into four possible quadrant levels in complex plane. Four can be represented in 2 bits. So, there are 2 bits to representlevels. Each pixel of normalized iris image represents by 2

Fig. 15. Process of Feature Extraction using Gabor Filter [4]

bits in iris template and generate 2,048 bits for the template. Also, masking bits will be generated for corrupted areas of iris pattern. Noise area intensities are calculated by averaging intensity levels of near bits to minimize influence. Generally, this creates 265 bytes of template.

Here it extracts phase information rather than information of amplitude because it provides significant information of patterns without depending on external factors such as illumination, contrast.

3) Hilbert transform: In [20], researcher introduce a method instantaneous-phase and/or emergent-frequency and it uses Hilbert Transformation to extract information from iris image. Using complex mathematical models, analytical image can be extracted which is constructed by original image and Hilbert transform combinely. In instantaneous phase, using analytic image, real and imaginary parts will be identified while emergent-frequency will be formed by three differ- ent dominant frequencies [20]. Finally similar mechanism to Daugman's system by thresholding will be used to calculate feature vector. As researcher claims, this approach is computationally effective.

4) Wavelet transform: Plenty of wavelet transformations are being used for feature extraction including, Haar wavelet [21], Fast wavelet [22], Hat wavelet and biorthogonal wavelet. Fast wavelet transform is designed to convert signal or waveform which in the time domain to a sequence of coefficients based on an orthogonal basis of small finite waves, or wavelets [22]. Initially this method starts by reading the greyscale image which is converted to predefined width and height. Then a linear array will be used to store the pixel values and start to perform fast wavelet transform encoding.

As researcher claims, this method is better than other methods because of it’s less complexity and computation speed is high [22].

Among other methods of feature extraction, wavelets transforms are being used over fourier transforms due to the fact that it uses space and frequency resolutions.

5) Local Binary Pattern: LBP or Local Binary Pattern isa type of visual descriptor used for classification. in [23],this method will be used to generate LBP image and extract features by chunked encoding method. LBP operator is simple yet very efficient texture operator which go through each and every pixels and label them by thresholding eight neighbours of pixels relative to center pixel. Then center pixel value will be calculated multiplying the converted neighborhood pixel values with weights to 2^n [24].

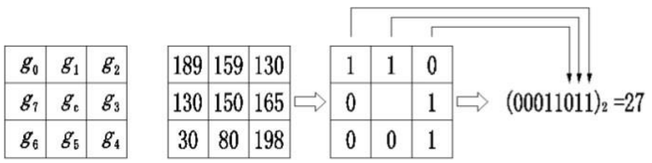


Fig. 16. The basic LBP operator [24]

Fig.16 demonstrates how does LBP operator calculates center pixel value by visiting to each and every pixel. After this operations, Fig.17 shows different feature images of different LBP operators.

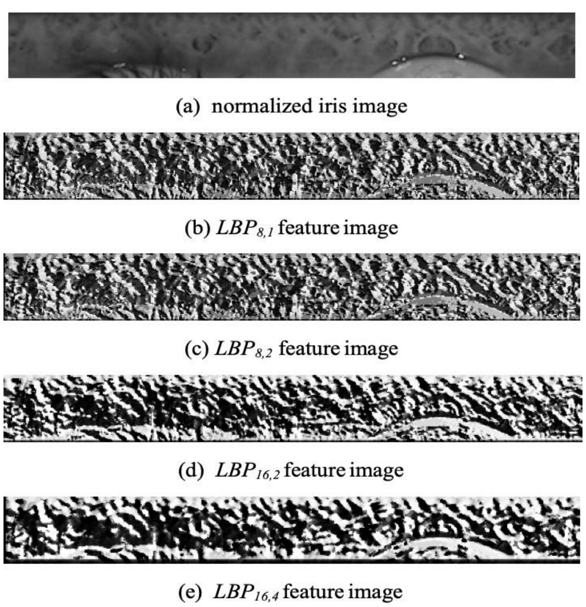


Fig. 17. Normalized iris image and its different LBP feature images [24]

After this LBP operation, as Fig.18 shows, chunk feature encoder will be invoked and feature code will be generated by going through top to bottom, from left to right in all defined blocks.

Researcher mentions that experimental results has shown that this algorithm can get higher recognition rate than the

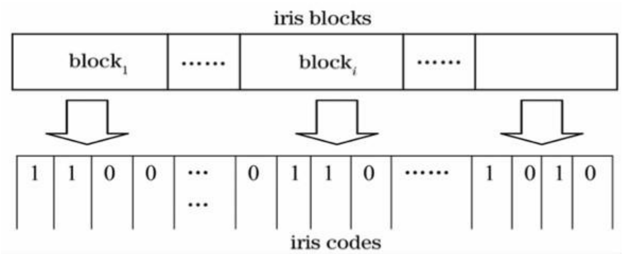


Fig. 18. Generation of the iris code [24]

traditional iris feature extraction method. According to 19, even though Daugman has 0.01% higher Correct recognition rate than proposed method by [24], still ERR of proposed method is significantly low.

Fig. 19. Comparison of recognition accuracy of various recognition schemes [24]

Recognition scheme	CRR(%)	EER(%)
Daugman[1]	99.61	0.32
Chunked encoding[12]	99.45	0.38
LBP[8]	-	0.86
Tan[7]	-	0.51
Proposed	99.60	0.26

6) Convolutional Neural Network: A study has provided an experimental approach to use deep convolutional features for iris recognition. Specifically tend to use this for feature extraction. Approach is using VGG-Net for iris recognition task [25]. Treating model as a feature extraction engine to extract features.

After extraction, image classification should be used to find corresponding label for iris image. There it was proposed to use multi-class SVM (Multi-Class Support Vector Machine) for iris image classification [25].

According to [25], there were experimental tests using IIT Delhi iris image database and CASIA-Iris-1000 database. Af- ter resizing training images for the network and after training, evaluation of recognition accuracy of fully connected layer (fc6) for different PCA (Principal Component Analysis) has been evaluated for both iris databases. Fig. 20 (a) and (b) shows accuracy levels and it has obtained 98% of accuracy level for IIT Delhi iris database images in 100 PCAs. Also 90% of accuracy has obtained for CASIA-Iris-1000 database images in 200 PCAs [25].

Also, for the evaluation of performance of the VGG-Netfor this task has shown high accuracy rate in Fig. 21 for any level after 7th layer, with 98% of minimum accuracy. Also, there is a drop of accuracy after level 11 and one reason for that could be when the neural network layers identify abstract data which do not discriminate iris patterns from one another as suggested in [25].

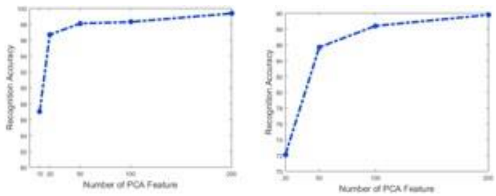


Fig. 20. (a) For IIT Delhi Recognition accuracy against Number of PCAs

(b) For CASIA-Iris-1000 Recognition accuracy for Number of PCAs [25]

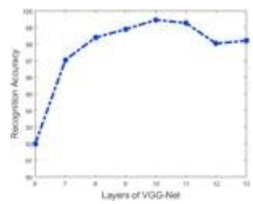


Fig. 21. Accuracy against VGG-Net Layers after 5th Layer [25]

E. *Template Matching*

After features being extracted and stored as feature templates in the database, there is a need of metric to match two templates to identify similarities and differences to make judgements. There has to define threshold value to identify inter class comparisons and inter class comparisons.

1) Hamming Distance: For matching one of the best solutions were Hamming distance [4]. Hamming distance is employed to do bit wise comparison which is necessary to identify similarities and differences.

$$HD = \frac{\|(codeA \otimes codeB) \cap maskA \cap maskB\|}{\|maskA \cap maskB\|} \tag{10}$$

In hamming distance, (XOR) operator has used to identify difference between any corresponding bits while operator ensures that both compared bits are not influenced by any external factor such as eyelids, eyelashes, illumination inconsistencies or different kind of noises. Then normalized values of numerator and denominator will use to calculate corresponding HD (Hamming Distance) [4]. Also, in hamming distance equation, Code A and Code B are bit pair of iris templates A and B which going to be compared. Mask A is corresponding mask values of that bit and same applies to Mask B. Thus, in [26], denominator part calculate total ofhow many bits were affected by external factors. So, this isa comparison of dissimilarity. If Hamming distance is zero, two templates are perfectly matching while if HD is 0.5, there two templates are independent. A threshold will be calculated afterwords to identify whether these iris templates are from same person or not.

Theoretically hamming distance of same intra-class comparisons should have 0. But because of different kind of factors like imperfect normalization, undetected noises may influence making identical templates. As mentioned in normalization, normalization could not address the problem of rotation when capturing the iris image. In order to achieve best comparison results, bit-wise shifting has been proposed by Daugman.

As proposed, bit-wise shifting done in horizontal way to correct original iris image capture rotations. If angular resolution 180 is used, each bit of shifting corresponds iris region's 2 degrees.

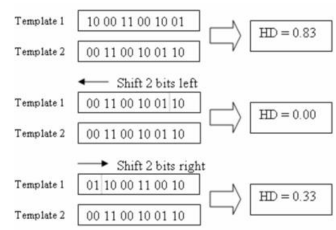


Fig. 22. Bit-wise shifting and template comparison [4]

First comparison has shown the hamming distance is 0.83 which says templates are independent. Since there may have rotational inconsistencies occurred, bit-wise shifting can be applied. First, shift two bits to left side and calculate hamming distance. Then again shift 2 bits to right side from the original location and calculate the hamming distance. Then the lowest hamming distance will be taken because that is the best match it can find. Since here lowest is HD = 0, it will take as a successful comparison.

2) Elastic Graph Matching: EGBM or Elastic Bunch Graph Matching or Elastic Graph Matching is an algorithm for recognizing objects or object classes in an image based on a graph representations of other images. [27] Template graph M_T will be compared against Image graph M_I which generated by set of points. Considering a cost function this matching will be carried out. As researcher shows, proposed EGM has higher CRR compared to popular feature matching methods, but still lower than 2D-Gabor filter technique introduced by Daugman in 1993.

3) Support vector machines: In machine learning, support- vector machines(SVM) are supervised learning models with associated learning algorithms that analyze data used for classification. In this [28], researcher has used SVM for featurematching. Since this is a binary classification of if this isa match or not, researcher highlights two aspects. First isthat the determination of the optimal hyperplane and other is transformation of non-linearly separable classification problem[28].

as Fig.23 shows, linear separable binary classification which has Class 1 and Class 2. It demonstrates a classification without any miss-classified data. Also in a linear separable problem, there is a linear boundary hyperplane which separatesthose data. if we consider it as,

$$w.x + b = 0 \tag{11}$$

it implies that,

$$y_i(w.x_i + b) \geq 1, i = 1, 2, ..., N \tag{12}$$

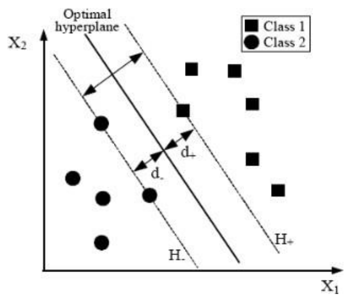


Fig. 23. SVM with Linear separable data. [28]

Using the above equations and considering the distance between hyperplanes, support vector machine will be able to classify data as researcher claims. Also if this is not categorized as a linear separable problem, using higher dimensions, it can transformed again into linear problem.

Researcher has used FRR and FAR to evaluate the SVM model and claims it has achieved excellent FAR values but FRR has to be improved.

4) Weighted Euclidean distance: In [16] they have used Weighted Euclidean distance to match feature templates. Weighted distance can be considered to find the most and least favorable situations. Thus, feature templates consists of numerical values can be used to find the most suitable feature template by reducing the distance according to Equation 13.

$$WED(k) = \sum_{i=1}^{N} \frac{(f_i - f_i^{(k)})^2}{(\delta_i^{(k)})^2} \tag{13}$$

K is the template, f_i denotes i^{th} feature, $f^{(k)}_i$ denotes ithfeature of the k^{th} template. N denotes total number of features extracted.

F. Template Security

Most important factor in iris recognition security system is keeping the iris templates secure [29].

1) Least Significant Bit method: Most of the times hackers are expecting to attack iris template databases. To keep these templates secure, LSB (Least Significant Bit) steganography can be used [29].

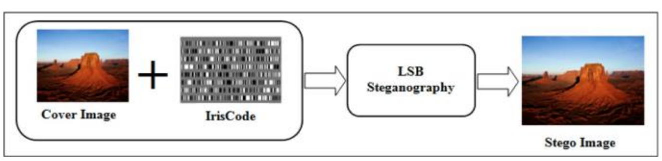


Fig. 24. Use Cover Image to hide Iris code. [29]

As in Fig.24, after extracting features from iris image and making the iris code, it uses 24 bits covering image and get LSB of color component blue to hide iris code. Then after generating random number sequence to hide the iris code,stego image can be get as the output and store in the database. When it comes to the recognition process, it gets the stego image from the database and obtain LSB in the stego image where iris code is hidden. Extract the iris code and using suitable template matching technique, compare templates [29].

2) Template Protection: In [30], researcher introduce several methods of iris template protection techniques. As ideal protection method should have following properties which are Diversity, Revocability, Security and Performance.

First what researcher discuss is feature transformation. this method also has two categories which are invertible and non-invertible feature transformation. invertible transformationuses techniques such as salting and bio-hashing to transform template features using a function specified to a particular user. This method has advantages such as low FAR, multiple transformed templates can be generated for the same user ...etc. This feature has one major issue which is if the user key is compromised, then the security for the template isno longer valid. in non-invertible transformation, one way functions such as hash functions will be used. Once the new template comes, a new hash value for that particular template will be generated and will compare against all the hash values of the database. Main advantage is that no one will be able to extract template even through the password is compromised. The main drawback of this method is the non-inversibility of the template.

Biometric Cryptosystems is new approach which is combining biometrics with cryptography to provide high level security for templates. n a biometric cryptosystem, some public information about the biometric template is stored. This public information is usually referred to as helper data and hence, biometric cryptosystems are also known as helper data-based methods [30].

III. Discussion

Most of the systems in iris recognition able to perform accurately upto some extent. But those are still can be tuned- up in stages like iris segmentation, eyelids and eyelashes detection, template matching, ..etc. A recent research has used completely CNN based solution for iris segmentation in dead subjects and as they have claimed, it has outperformed some commercial product algorithms.Another research from 2019 have find a promising method to process segmentedimage for image normalization if segmentation carryout by a DCNN model. These researches indicates how accuratelywe can carry out these phases by acquiring the machine learning models such as deep convolutional neural networks. We believe, if that worked for dead subjects, this may also can be used for living subjects as well after few adjustments. Image acquisition phase can be further improved with thehelp of fuzzy image processing and advanced image sensors. Even if the image sensor failed to stonewall the affects of glare, Homomorphic filtering can be used upto some extent to remove these non-uniform illuminations before sending captured image for image segmentation.

Similarly, feature extraction and feature matching should beable to improve further. Few years back some researchers have work hard to find efficient feature extraction methods based on CNNs and as results indicate, they have succeeded. But the main issue which is clearly visible, is that the use of famous iris databases for training. These data sets comprise images that are captured under controlled condition and they do not cover almost all the practical situations such as glares appear with eye glasses. These possible scenarios are mandatory in neural network training to get best results and publiclyavailable data sets can be used to validation and testing of proposed models. Since the release of latest google database search engine, researchers can find images across different databases which will cover all possible scenarios under real environment conditions and researchers can create their own data sets for training.

IV. Conclusion

This paper provides a review of well-known iris recog-nition algorithms that are proposed by different researchers from time to time. Almost all the researches follow mainsteps of iris recognition which are acquisition, segmenta- tion, normalization, feature extraction and feature matching. Currently methods which uses machine learning models like DCNN, CNN, Capsule networks shows good results compared to similar researches. As discussed in Discussion phase, if researchers accommodate proposed improvements, we believe these researches and field can be further improved.

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The Dataset employed :

we found an Available Dataset on Kaggle (a public one):

https://www.kaggle.com/datasets/amnahali/iris-recognition

Details of the algorithm(s)/approach(es) that will be :

Neural Network Definition:

Function approximation, or regression analysis, including time series prediction Classification, including pattern and sequence recognition, novelty detection and sequential decision making. - Data processing, including filtering, clustering, blind signal separation and compression.

Neural nets are composed of layers. - The input layer takes the data in. It’s not a computational layer. - The computational layer is the hidden

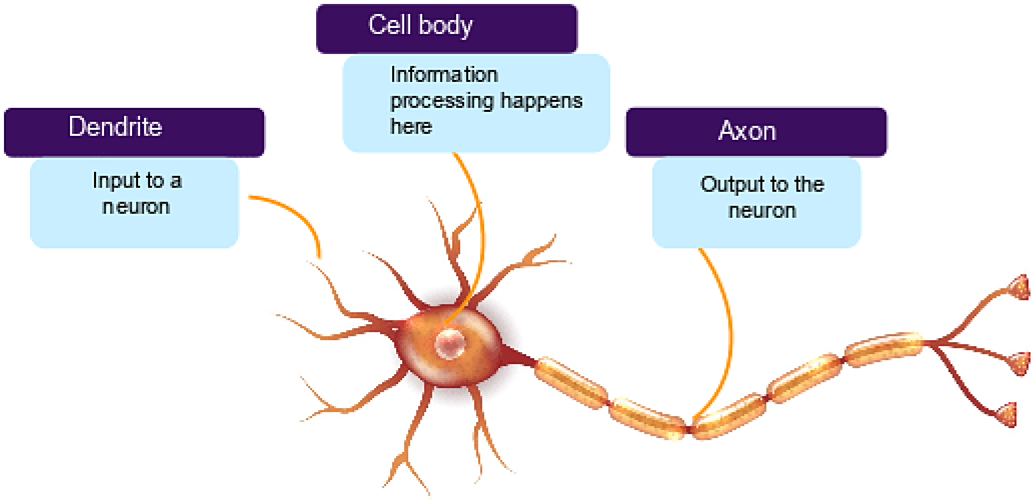
A neural network is a system or hardware that is designed to operate like a human brain.

Neural networks can perform the following tasks:

- Translate text
- Identify faces
- Recognize speech
- Read handwritten text
- Control robots

What Is a Neural Network?

To understand how an artificial neuron works, we should first understand how a biological neuron works.



Dendrites

These receive information or signals from other neurons that get connected to it.

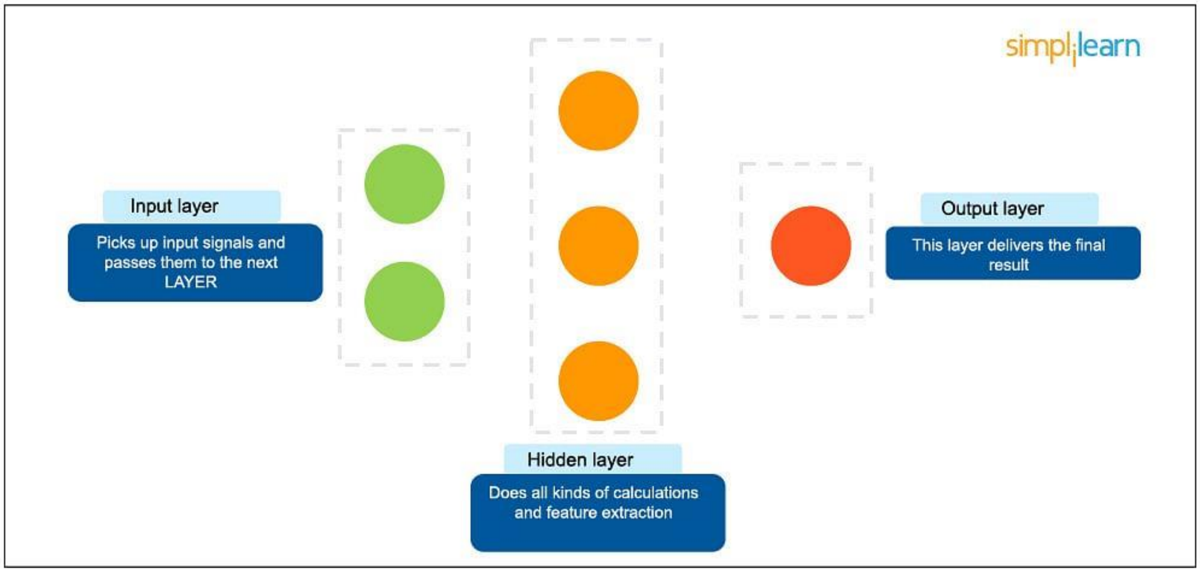
Cell Body

Information processing happens in a cell body. These take in all the information coming from the different dendrites and process that information.

Axon

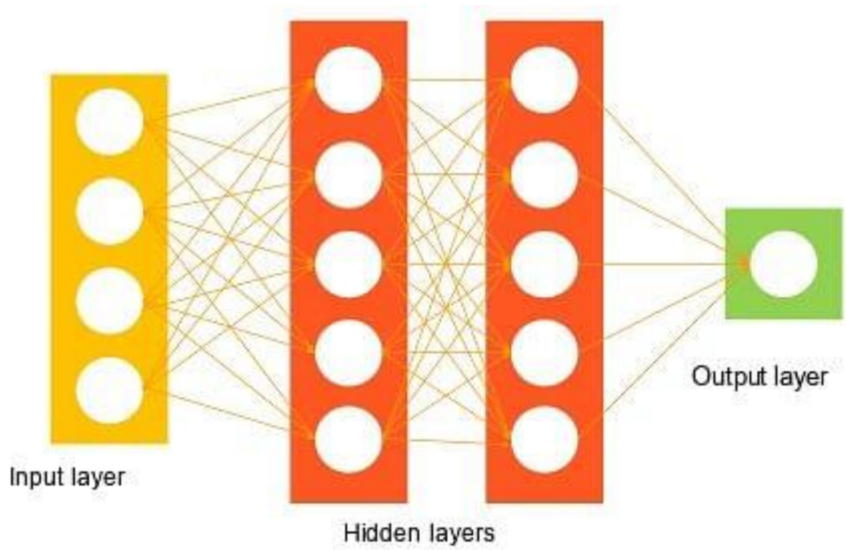
It sends the output signal to another neuron for the flow of information. Here, each of the flanges connects to the dendrite or the hairs on the next one.

Working of Neural Network



A neural network is usually described as having different layers. The first layer is the input layer, it picks up the input signals and passes them to the next layer. The next layer does all kinds of calculations and feature extractions—it's called the hidden layer. Often, there will be more than one hidden layer. And finally, there's an output layer, which delivers the final result

The image shown below depicts an ANN



Applications of Neural Network

With an enormous number of applications implementations every day, now is the most appropriate time to know about the applications of neural networks, machine learning, and artificial intelligence. Some of them are discussed below:

Handwriting Recognition

Neural networks are used to convert handwritten characters into digital characters that a machine can recognize.

Traveling Issues of sales professionals

This application refers to finding an optimal path to travel between cities in a given area. Neural networks help solve the problem of providing higher revenue at minimal costs. However, the Logistical considerations are enormous, and we must find optimal travel paths for sales professionals moving from town to town.

Image compression

The idea behind neural network data compression is to store, encrypt, and recreate the actual image again. Therefore, we can optimize the size of our data using image compression neural networks. It is the ideal application to save memory and optimize it

Iris recognition

an automated method of biometric identification that uses mathematical pattern-recognition techniques on video images of one or both of the irises of an individual's eyes, whose complex patterns are unique, stable, and can be seen from some distance

Speech recognition

Neural networks can analyze human speech despite varying speech patterns, pitch, tone, language, and accent. Virtual assistants like Amazon Alexa and automatic transcription software use speech recognition to do tasks like these:

- Assist call center agents and automatically classify calls
- Convert clinical conversations into documentation in real time
- Accurately subtitle videos and meeting recordings for wider content reach

Future of Neural Networks

Hyper-intelligent virtual assistants will make life easier. If you have ever used Google assistant, Siri, or any other products, you can see how they're slowly evolving. They may even predict your email responses in the future!

We can also expect intriguing discoveries on algorithms to support learning methods. However, we are just in the infant stage of applying artificial intelligence and neural networks to the real world.

Neural networks will be a lot faster in the future, and neural network tools can get embedded in every design surface. We already have a little mini neural network that plugs into an inexpensive processing board or even into your laptop. Instead of the software, focusing on the hardware would make such devices even faster.

Neural networks will also find their way into the fields of medicine, agriculture, physics, research, and anything else you can imagine. Neural networks will also find its way into the fields of medicine, agriculture, physics, research, and anything else you can imagine

Types of Neural Networks

Feed-forward Neural Network

This is the simplest form of [ANN (artificial neural network)](); data travels only in one direction (input to output). This is the example we just looked at. When you actually use it, it's fast; when you're training it, it takes a while. Almost all vision and speech recognition applications use some form of this type of neural network.

Radial Basis Functions Neural Network

This model classifies the data point based on its distance from a center point. If you don't have training data, for example, you'll want to group things and create a center point. The network looks for data points that are similar to each other and groups them. One of the applications for this is power restoration systems

Self-organizing Neural Network

Vectors of random input are input to a discrete map comprised of neurons. Vectors are also called dimensions or planes. Applications include using it to recognize patterns in data like a medical analysis.

Recurrent Neural Network

In this type, the hidden layer saves its output to be used for future prediction. The output becomes part of its new input. Applications include text-to-speech conversion

Convolution Neural Network

In this type, the input features are taken in batches—as if they pass through a filter. This allows the network to remember an image in parts. Applications include signal and image processing, such as facial recognition

Modular Neural Network

This is composed of a collection of different neural networks working together to get the output. This is cutting-edge and is still in the research phase

What are neural networks used for?

Neural networks have several use cases across many industries, such as the following:

- Medical diagnosis by medical image classification
- Targeted marketing by social network filtering and behavioral data analysis
- Financial predictions by processing historical data of financial instruments
- Electrical load and energy demand forecasting
- Process and quality control

Chemical compound identification

Important Algorithms for training Neural Networks:

- **Gradient Descent** — Used to find the local minimum of a function.
- **Evolutionary Algorithms** — Based on the concept of natural selection or survival of the fittest in Biology.
- **Genetic Algorithm** — Enable the most appropriate rules for the solution of a problem and select it. So, they send their 'genetic material' to 'child' rules. We will learn about them in details below.

Advantages of Neural Network:

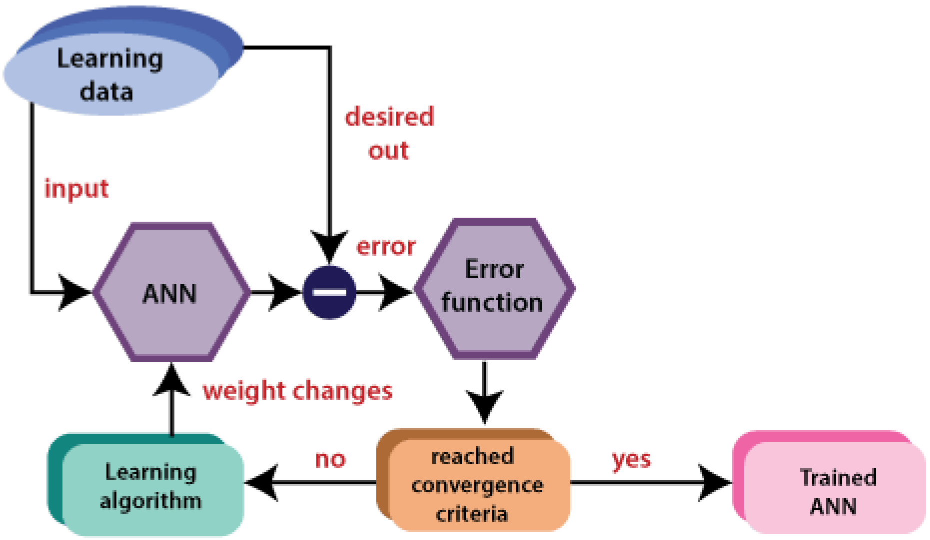
This neural network has the potential for high fault tolerance and can debug or diagnose a network on its own. ANN can go through thousands of log files from a company and sort them out. It is currently a tedious task done by administrators, but it will save a significant amount of time, energy, and resources if it can be automated

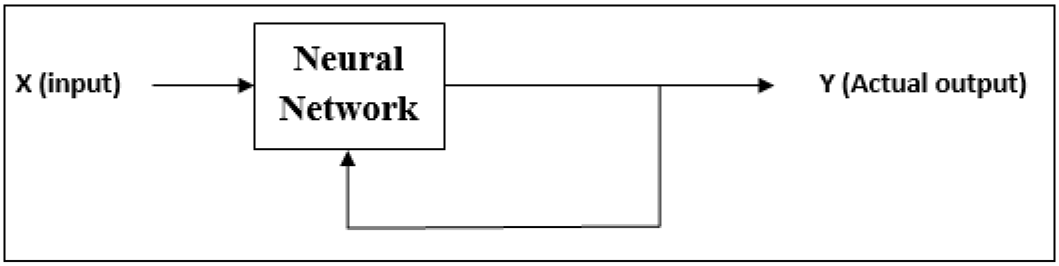
Disadvantages of Artificial Neural Network

The disadvantages of the neural network are as follows, The neural network required training to operate, The structure of a neural network is disparate from the structure of microprocessors therefore required to be emulated, It needed high processing time for big neural networks

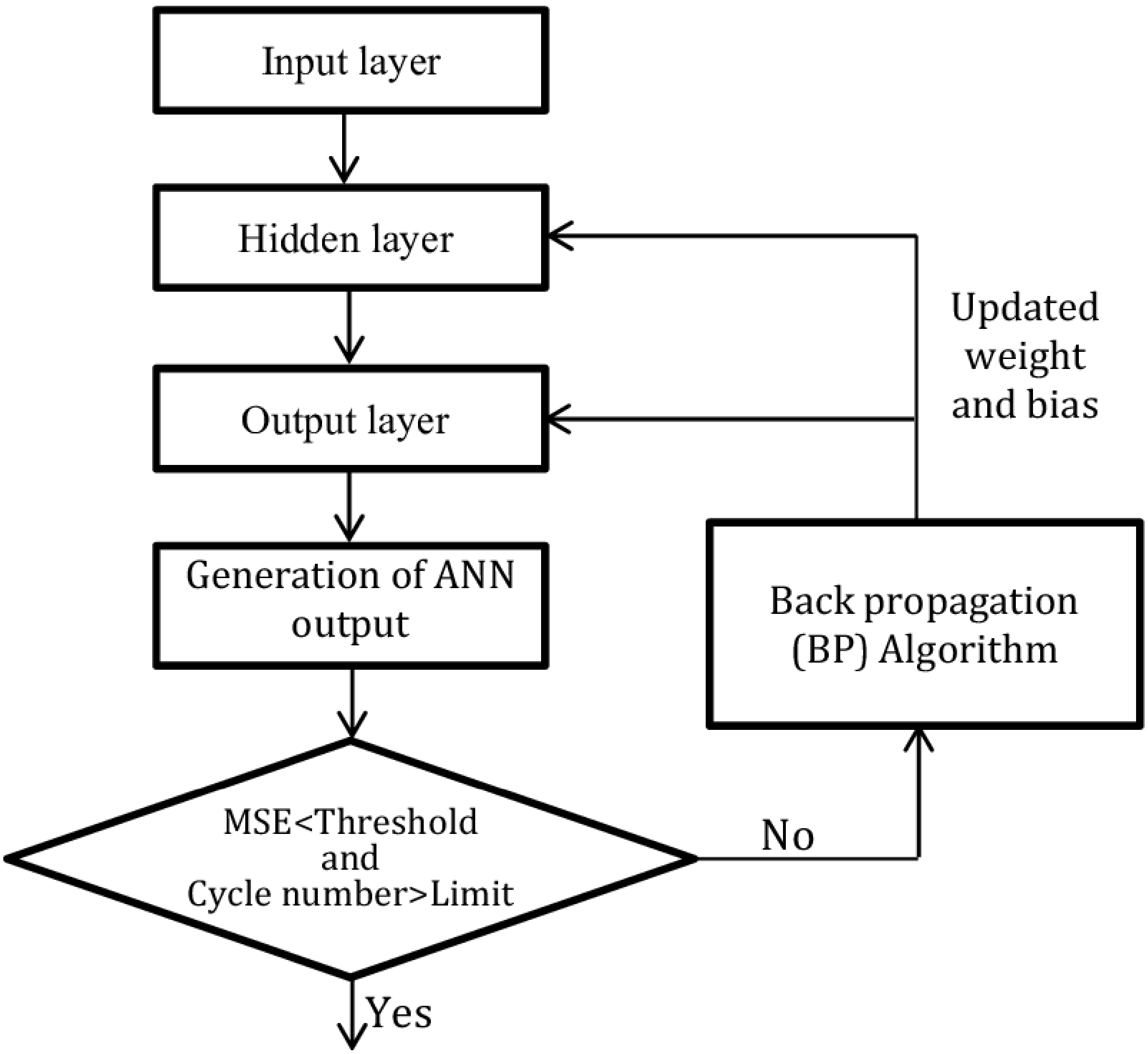
Phase 2

Block Diagrams

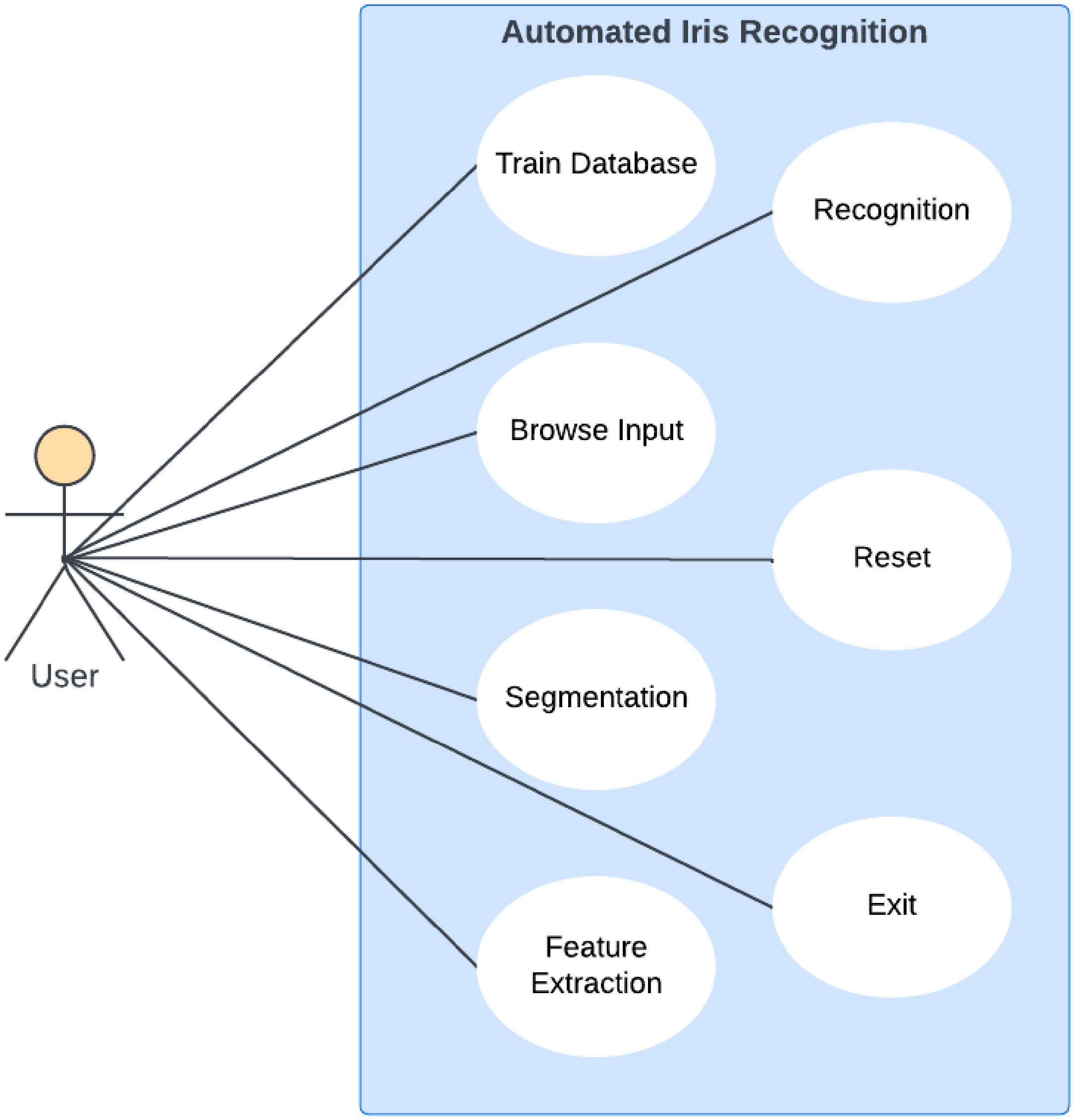




Flowcharts


Input layer
Hidden layer
Output layer
Generation of ANN output
MSE<Threshold
and
Cycle number>Limit
Yes
No
Back propagation (BP) Algorithm
Updated weight and bias

Use case


Automated Iris Recognition
Train Database
Recognition
Browse Input
Reset
Segmentation
Exit
Feature Extraction
User

Detailed use-case description

User case name	Segmentation
ID	NW1
Goal	converting an image into a collection of regions of pixels that are represented by a mask or a labeled image,
Actor	User
Pre-condition	Inter the image
Post-condition	Image is Segmentation successfully
Main scenario	**steps** 1. Enter Image. 2. Converting image int collection of pixels. 3. Process the important segments of the image.
Alternative scenario	**steps** 1. Invalid image. 2. Print invalid image. 3. Can't recognition to the image.

User case name	Feature Extraction
ID	NW2
Goal	refers to the process of transforming raw data into numerical values features, distinguish objects from one another
Actor	User
Pre-condition	Raw data
Post-condition	Numerical values (features).
Main scenario	**steps** 1. Enter image. 2. Preprocessing the image (Crop and resize). 3. Calculate the Gradients, Magnitude and Orientation.
Alternative scenario	**steps** 1. Can't transforming raw data into numerical values 2. Mack a Preprocessing on raw data 3. Can't recognition to the image.

A literature review of Academic publications (5 papers)

Standard Iris Storage Formats

Iris recognition standards are open specifications for iris cameras, iris image properties, and iris image records. Biometric data standards are a necessity for applications in which a consumer of a data record must process biometric input from an arbitrary producer. The archetype for standard iris storage formats has been the flight of standards already developed for the storage of biometric data on electronic passports.

Iris Quality Metrics for Adaptive Authentication

Iris sample quality has a number of important applications. It can be used at a variety of processing levels in iris recognition systems, for example, at the acquisition stage, at image enhancement stage, or at matching and fusion stage. Metrics designed to evaluate iris sample quality are used as figures of merit to quantify degradations in iris images due to environmental conditions, unconstrained presentation of individuals or due to postprocessing that can reduce iris information in the data. This chapter presents a short summary of quality factors traditionally used in iris recognition systems. It further introduces new metrics that can be used to evaluate iris image quality. The performance of the individual quality measures is analyzed, and their adaptive inclusion into iris recognition systems is demonstrated. Three methods to improve the performance of biometric matchers based on vectors of quality measures are described. For all the three methods, the reported experimental results show significant performance improvement when applied to iris biometrics. This confirms that the newly proposed quality measures are informative in the sense that their involvement results in improved iris recognition performance.

Quality and Demographic Investigation

There have been four major experimental evaluations of iris recognition technology in recent years: the ITIRT evaluation conducted by the International Biometric Group, the Iris '06 evaluation conducted by Authenti-Corp, and the Iris Challenge Evaluation (ICE) 2006 and Iris Exchange (IREX) conducted by the National Institute of Standards and Technology. These experimental evaluations employed different vendor technologies and experimental specifications, but yield consistent results in the areas where the specifications intersect. In the ICE 2006, participants were allowed to submit quality measures. We investigate the properties of their quality submissions.

Methods for Iris Segmentation

Under ideal image acquisition conditions, the iris biometric has been observed to provide high recognition performance compared to other biometric traits. Such a performance is possible by accurately segmenting the iris region from the given ocular image. This chapter discusses the challenges associated with the segmentation process, along with some of the prominent iris segmentation techniques proposed in the literature. The methods are presented according to their suitability for segmenting iris images acquired under different wavelengths of illumination. Furthermore, methods to refine and evaluate the output of the iris segmentation routine are presented. The goal of this chapter is to provide a brief overview of the progress made in iris segmentation.

An iris acquisition system typically captures an image of the eye that, besides the iris, includes the pupil, eyelids, eyelashes, and sclera. The process of locating and isolating the iris from such an image is known as irislocalization orsegmentation. The primary task of segmentation is to determine the pixels in a given image that correspond to the iris region., the pupillary boundary refers to the boundary separating

the pupil (the black region in the center of the eye) from the iris (the textured region surrounding the pupil) while the limbus boundary refers to the boundary separating the iris from the sclera (the white of the eye). Typically, segmentation is accomplished by detecting the pupillary and limbus boundaries as well as the eyelids and eyelashes that can interrupt the contour of the limbus boundary.

Iris Recognition with Taylor Expansion

The random distribution of features in an iris image texture allows to

perform iris-based personal authentication with high confidence. In this chapter we describe three iris representations. The first one is a phase-based iris texture representation which is based on a binarized multi-scale Taylor expansion. The second one describes the iris by using the most significant local extremum points of the first two Taylor expansion coefficients. The third method is a combination of the first two representations. For all methods we provide efficient similarity measures which are robust to moderate iris segmentation inaccuracies. Using three public iris datasets, we show (a) the compact template size of the first two representations and (b) their effectiveness: the first two representations alone perform well already, but in combination, they outperform state-of-the-art iris recognition approaches significantly.

The iris segmentation process consists of mainly three steps [1, 2, 3]: (1) localizing the inner and outer boundaries of the iris, (2) the optional detection of occluding upper and lower eyelids, and (3) the detection and removal of reflections on the cornea or the eyeglasses. For iris segmentation, we use standard state-of-the-art image processing techniques.

Application of Correlation Filters for Iris Recognition

Excellent recognition accuracies have been reported when using iris images, particularly when high-quality iris images can be acquired. The best-known strategy for matching iris images requires segmenting the iris from the background, converting the segmented iris image from Cartesian coordinates to polar coordinates, using Gabor wavelets to obtain a binary code to represent that iris and using the Hamming distances between such binary representations to determine whether two iris images match or do not match. However, some of the component operations may not work well when the iris images are of poor quality, perhaps as a result of the long distance between the camera and the subject. One approach to matching images with appearance variations is the use of correlation filters (CF). In this chapter, we discuss the use of CFs for iris recognition. CFs exhibit important benefits such as shift-invariance and graceful degradation and have proven worthy of consideration in other pattern recognition applications such as automatic target recognition. In this chapter, we will discuss the basics of CF design and show how CFs can be used for iris segmentation and matching

Iris Segmentation

Before two iris patterns can be compared, they need to be segmented from the rest of the image. Most iris segmentation approaches rely on the fact that, in gray scale images, the pupil (that is interior) to the iris is usually darker than the iris region and the sclera (on the outside) is brighter than the iris. So, iris boundaries can be detected by looking for regions with large gradient magnitudes (e.g., from pupil to iris and from iris to sclera) as was proposed originally in using integro-differential operators for iris boundary detection. Another useful feature of iris boundaries is that they may be nearly circular suggesting the use of circular Hough transforms to identify iris boundaries. More recently, improved iris segmentation results have been obtained using active contours techniques. In this section, we discuss a cross-correlation based method for iris segmentation.

Introduction to the IrisCode Theory

IrisCode is the most successful iris recognition method. Developed for

over 18 years, IrisCode still dominates the market even though numerous iris recognition algorithms have been proposed in the academics. Currently, more than

60 million people have been mathematically enrolled by this algorithm. Its computational advantages, including high matching speed, predictable false acceptance

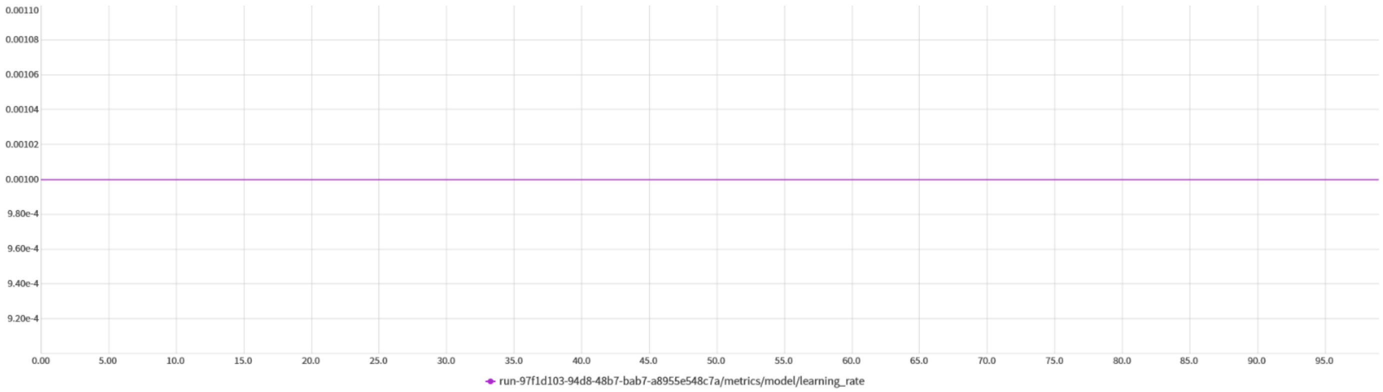
rates and robustness against local brightness and contrast variations, play a significant role in its commercial success. To further these computational advantages,

researchers have modified this algorithm to enhance iris recognition performance and recognize other biometric traits (e.g. palmprint). Many scientific papers on iris recognition have been published, but its theory is almost completely ignored. In this chapter, we will report our most recent theoretical work on the IrisCode.

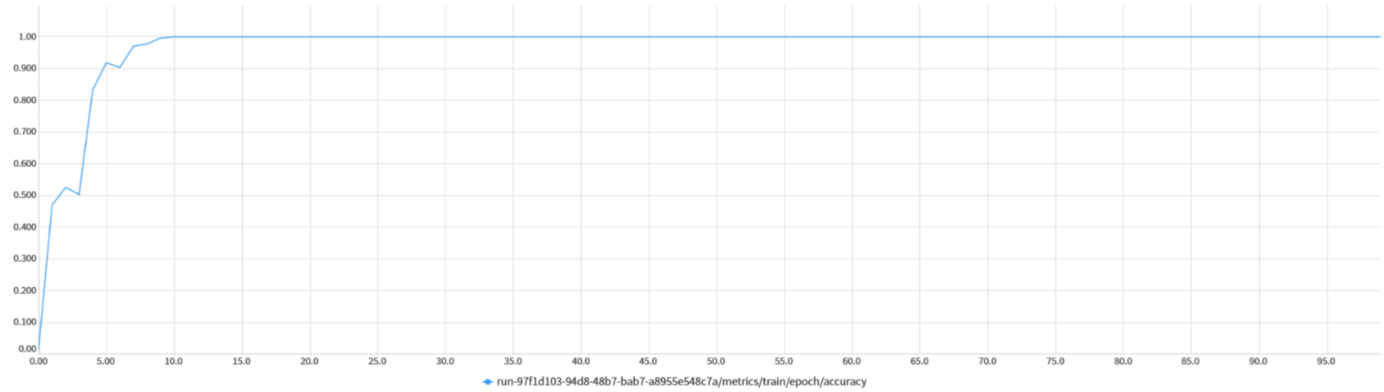
PLOTS

First test

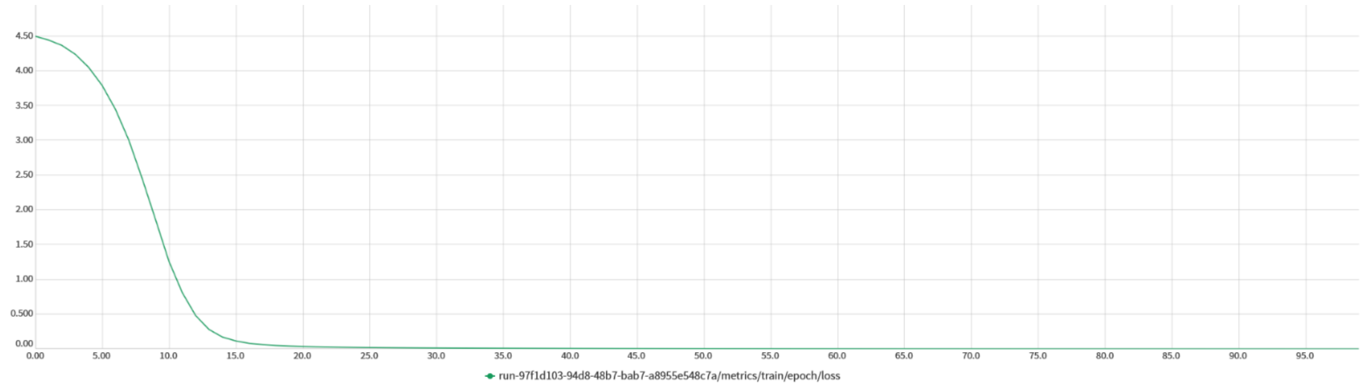
Learning rate



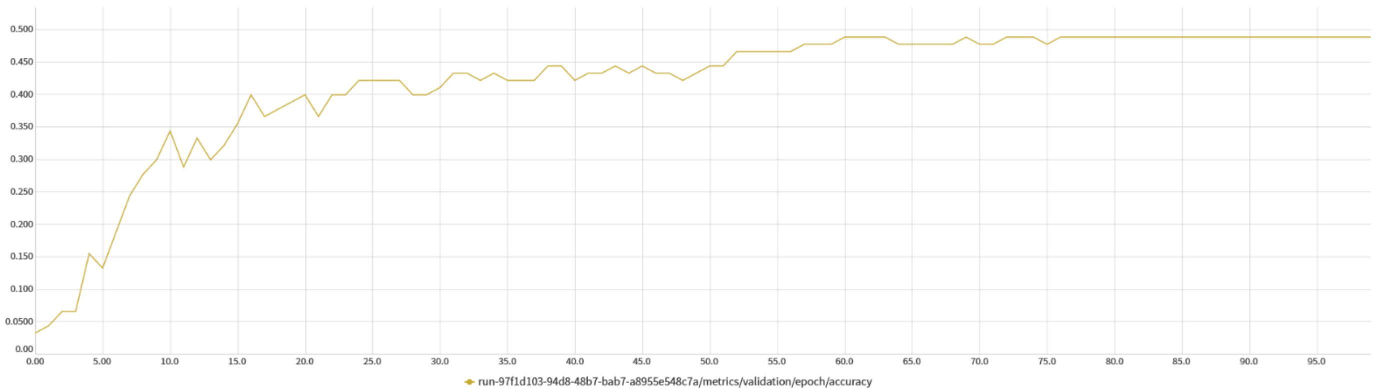
Accuracy of train



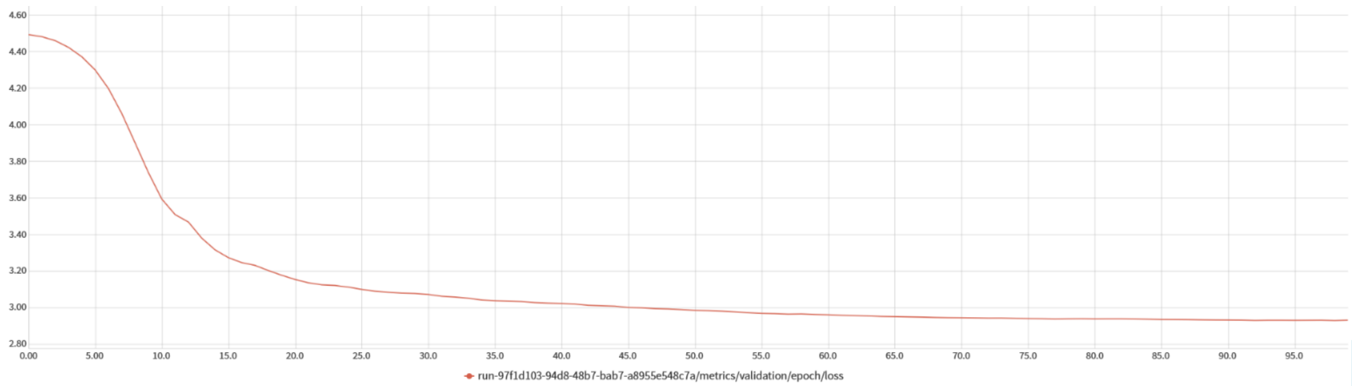
Loss of train



Validation of accuracy

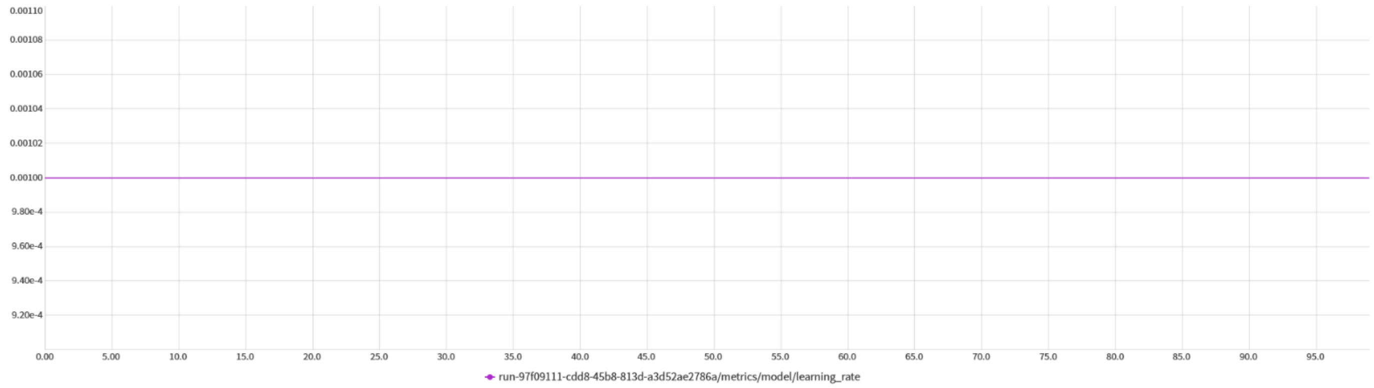


Validation of loss

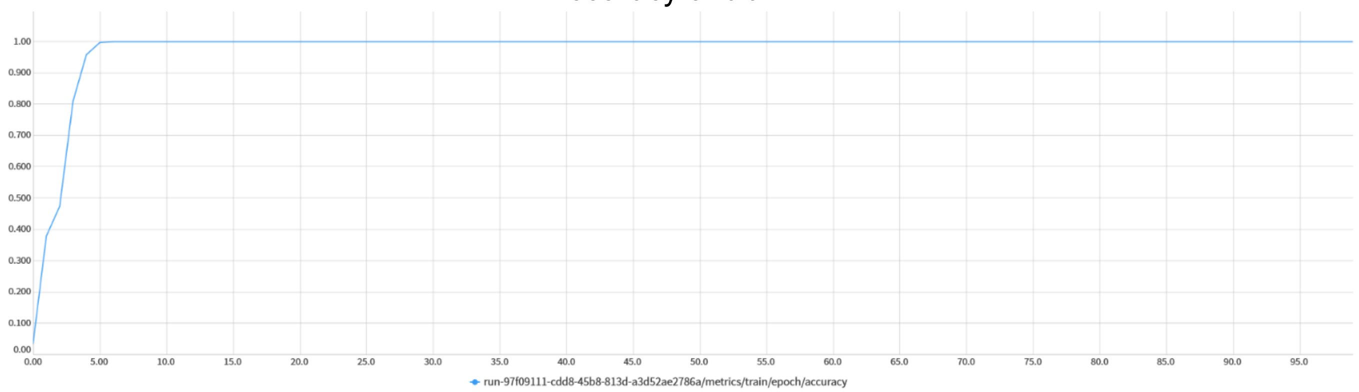


After optimization

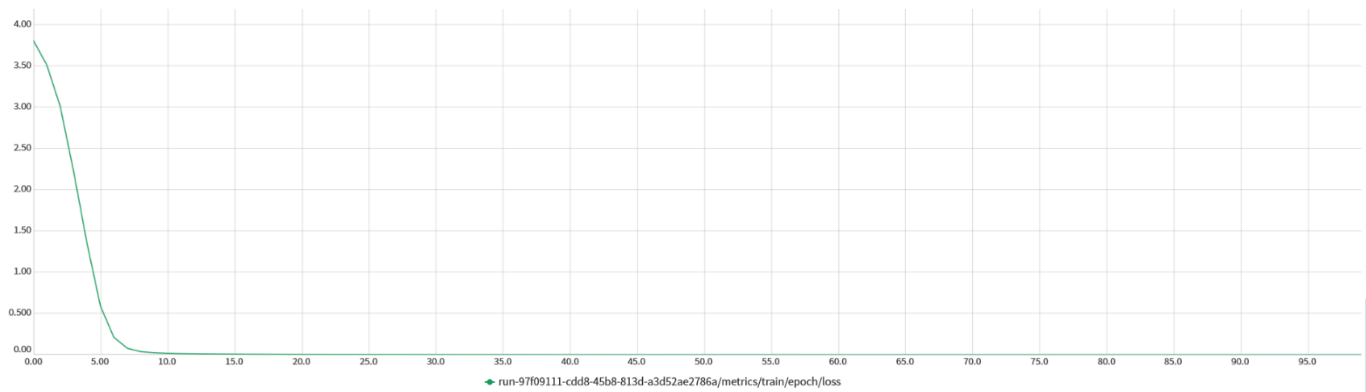
Learning rate



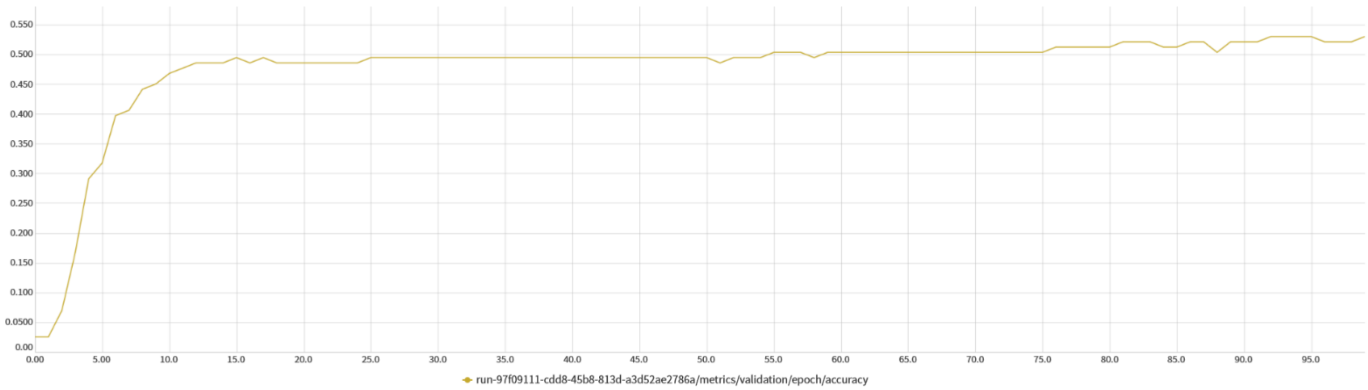
Accuracy of train



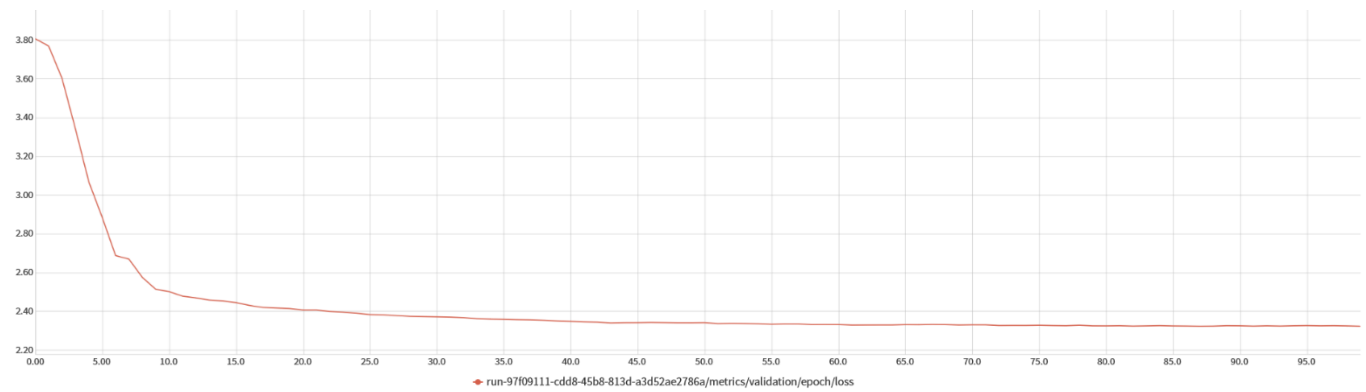
Loss of train



Validation of accuracy



Validation of loss



Results of the experiments

Import an Iris image, it is **expected** whether the **Iris** is **existed** on the database **or not**.

By using some methods like:

1. Feature extraction
2. Segmentation
3. Localization

The Expected result is the Iris's ID for the imported image if found.

Development Platforms

1- Code Editors(IDE) :

Jupyter - vsCode

2- Kaggle website
3- Python libraries :

Matplotlib – TensorFlow – Numpy – pandas – OpenCV – sklearn – pickle - keras