Design & Development of IRIS Biometric systems – A exhaustive review summary & problem formulation

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***Abstract*—In this paper, a brief review of the research work taken up on the biometric recognition system using the human part of the eye, i.e., the iris part is being considered. In the sense, the paper relates to the first chapter of the research work, which is the introductory part. Also, the motivation obtained to pursue the work on this topic is being presented, which has lead us to the definition of the problem & stated as the problem statement of the Ph.D. research work.**

Keywords—Biometrics, Iris, Authentication, Recognition, Identification, Classifiers, Simulation, Matlab, LabVIEW, Neural Network, Database, Image, Pre-processing, Segmentation, Algorithm, Histogram, Filter, Edge Detection, Normalization, Wavelets, Coding, GUI, Unconstraints, Constraints, Hardware, Software, Implementation.

I. INTRODUCTION TO BIOMETRICS

Biometrics is the art of identifying a human being by different methods. Identifying or verifying one identify using biometrics is attracting considerable attention in this modern day automated world, one the main reason being the security issues in various places. Biometrics is the beautiful science of automatic identification of individuals that uses the unique physical or behavioral traits/characteristics of individuals to recognize them. Since biometrics is extremely difficult to forge and cannot be forgotten or stolen, biometric authentication offers a convenient, accurate, irreplaceable and high secure alternative for an individual, which makes it has advantages over traditional cryptography-based authentication schemes.

In today's statistics technology, security for systems is turning into increasingly more essential. The range of structures which have been compromised is ever increasing and authentication plays a primary role as a first line of defense against intruders. Modern day *e*-safety are in critical need of locating accurate, comfortable and cost-effective alternatives to passwords and personal identity numbers as financial losses increase dramatically year over year from PC-based fraud including computer hacking and identity theft. Biometric answers deal with those fundamental troubles, because an individual's biometric statistics particular and cannot be transferred.

It has become a hot interdisciplinary topic involving biometric and Cryptography. Biometric data is personal privacy information, which uniquely and permanently associated with a person and cannot be replaced like passwords or keys. Once an adversary compromises the biometric data of a user, the data is lost forever, which may lead to a huge financial loss. Hence, one major concern is how a person's biometric data, once collected, can be protected and thus the security issues of the stored biometric data of the human beings also has to be taken into account. The 3 essential varieties of any biometric authentication scheme are,

viz., something you already know (inclusive of a password), something you've got (inclusive of a card or token) and something you're (biometric).

Passwords are notorious for being vulnerable and easily crackable due to human nature and tendency to make passwords easy to don't forget or writing them down someplace without difficulty available. Cards and tokens may be supplied via all people and although the token or card is recognizable, there may be no manner of knowing if the person offering the card is the actual proprietor or the owner.

Biometrics, alternatively, presents a secure approach of authentication and identity, as they're hard to duplicate and use it by someone else other than the owner of the biometric. If biometrics is used together with something you recognize, then this achieves what is called two-factor authentication. Two-point authentication is an awful lot & has more potential as it requires both additives capturing & identification.

Biometrics provides secured authentication because it uses the biological properties of the human beings, so it cannot be forged and stolen by others. Authentication systems based on the biometrics are estimated to perform better than the other two identification methods because they depend on who you are rather than on what you possess, such as an ID card, or what you remember, such as a password. Because of the reliability and accuracy of the biometrics system, it has the capability to replacing the traditional authentication systems like passwords and ID card.

The advantages & the disadvantages of the biometrics are mentioned below :

Advantages : uniqueness, universality, user friendly, accuracy, comfort.

Dis-advantages : costly, facial imaging can also hinder accurate identification, missing or injured body part problem, occlusion, false acceptance & rejection, scanning of eye is fearful to some people.

II. History and Development of Biometrics

The idea of using patterns for personal identification was originally proposed in 1936 by ophthalmologist Frank Burch. By the year 1980's, the idea had appeared in James Bond films, but it still remained as a science fiction and conjecture. In 1987, two other ophthalmologists Aram Safir and Leonard Flom patented this idea and in 1987 they asked John Daugman to try to create actual algorithms for this iris recognition. These algorithms which Daugman patented in the year 1994 are the basis for all current iris recognition systems and products.

Daugman's algorithms are owned by Iridian technologies and the process was licensed to several other companies who serve as system integrators and developers of special platforms exploiting the iris recognition in recent years & several products have been developed for acquiring its images over a range of distances and in a variety of applications across the world.

One active imaging system developed in 1996 by licensee Sensor deployed special cameras in bank ATM to capture IRIS images at a distance of up to 1 meter. This active imaging system was installed in cash machines both by NCR Corps and by Diebold Corp in successful public trials in several countries during 1997 to 1999. A new and smaller imaging device is the low cost "*Panasonic Authenticam*", a digital camera for handheld, desktop, *e*-commerce and other information security applications.

Ticket less air travel, check-in and security procedures based on iris recognition kiosks in all domestic & international airports have been developed by iris companies. Companies in several countries are now using Daugman's algorithms in a variety of products. The need of personal identification has increased a lot during the recent times. As biometric technique, iris recognition is getting preference over other methods and has drawing greater attention of scientists because of its uniqueness, non-invasiveness and stability of human iris patterns. So many commercial systems have been developed in order to treat the eye images and perform identification or the verification procedures.

III. Types of Biometric Devices Used in BM Technology

The *biometric technology* comprises of an entire biometric identification & authentication system (*both at the hardware level & at the software level*). First, there will be a device for capturing the biometric, then an electronic system for analysis & then a computing system for processing, a software for processing the captured biometry & storing and finally a output device (display) for visual seeing of the captured biometry. This involves the cameras, LCDs, scanners, electronic gadgets (smart phones), mini-computers, aadhar identification kits, etc…

The biometrics generally refers to the identification or authentication of a man or woman primarily based on positive particular capabilities or traits which has capability to differentiate between legal person and an imposter. A realistic biometric machine should have suitable popularity accuracy, pace with affordable resource requirements (also it should be cost-effective). It must be harmless to users, be familiar by means of the intended populace, and be sufficiently robust to diverse fraudulent methods.

Fig. 1 : Types of biometric devices-physiological & behavioural-1

A bonus advantage of the use of biometric authentication is that it cannot be misplaced or forgotten, as the person must be physically present at some point of on the factor of identity

method. Biometrics is inherently extra reliable and capable than conventional knowledge, primarily based and token based techniques. The 2 classes of biometric identifiers are mainly the physiological and behavioral traits. The Iris, fingerprint, speech/voice, face, retina, DNA and many others belong to the former kind of biometric identifiers at the same time as typing rhythm, gait, voice, and so on…. belongs to the latter traits.

Fig. 2 : Types of biometric devices-physiological & behavioural-2

Fig. 3 : Biometric device - Retina scan machine

Fig. 4 : Biometric device-Finger Palm print

Fig. 5 : Type of biometric device-Face recognition

Fig. 6 : Biometric device-Voice recognition

Fig. 7 : Biometric device-Thumb

Fig. 8 : Biometric device-Iris scan

Fig. 9 : Biometric device-Palm & Finger

Fig. 10 : Biometric device-Palm

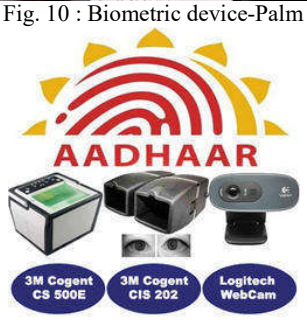

Fig. 11 : Biometric devices - Aadhar tool kit

A biometric machine normally features by means of first capturing a pattern of the characteristic, such as shooting a digital color picture of a face to be used in facial recognition or a recording a digitized sound sign for use in voice recognition. The pattern may then be processed so that the max^{m}. discriminating capabilities can be extracted & noises inside the sample are reduced. The pattern is then transformed into a biometric template by the usage of some sort of mathematical features. Different types of biometric devices in common use across the world are shown in the Figs. 1 to 11 respectively.

The biometric template is a normalized and efficient illustration of the sample which can be used for comparisons between the stored sample & the actual sample when the sample comes in front of the device. Biometric systems commonly have 2 modes of operations, viz., the enrolment mode & the identity mode. An enrolment mode is used for adding new templates into the database and the identity mode is used for comparing a template created for a person, who wants to be proven, with all the prevailing templates in the database.

An excellent biometric is one which uses a function this is relatively precise, compact, fast & reliable even in case of rough usage. This reduces the chances of any humans having the equal traits to the minimum. The feature need to additionally be strong in order that it does no longer trade over the time frame.

IV. BASIC STRUCTURE OF A TYPICAL BIOMETRIC SYSTEM

A biometric system consists of 3 important parts, viz., capturing phase (image acquisition), processing phase, identification & classification phase. A basic biometric system is shown below in the Fig. 12 & can operate in different phases. Biometric recognition requires comparing a registered or enrolled biometric sample (*biometric template or identifier-database*) against a newly captured biometric sample (*for example, a scan iris image of a human being*). During enrollment as shown in the Fig. 13, a sample of the biometric trait is captured, processed by a computer, and stored for later comparison, which is nothing but a template matching technique or a pattern recognition technique that could be used in image processing or computer vision.

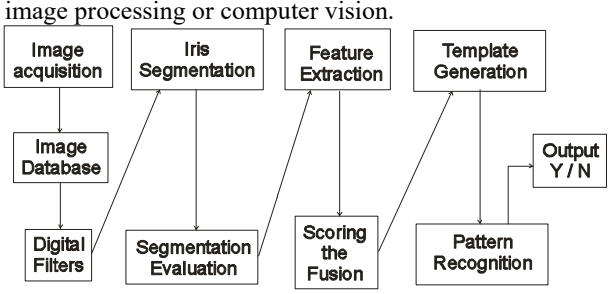

Fig. 12 : Block diagram of a typical biometric scheme for the iris recognition-I

Biometric recognition can be used in identification mode, where the biometric system identifies a person from the entire enrolled population by searching a database for a match based solely on the biometric. For example, an entire database can be searched to verify a person has not applied for entitlement benefits under two different names. This is sometimes called "*one-to-many*" matching and the concept of how the iris is recognized from a database is shown pictorially in the Fig. 14.

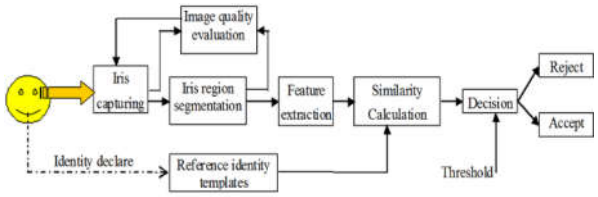

Fig. 13 : Block diagram of a typical biometric scheme for the iris recognition-II

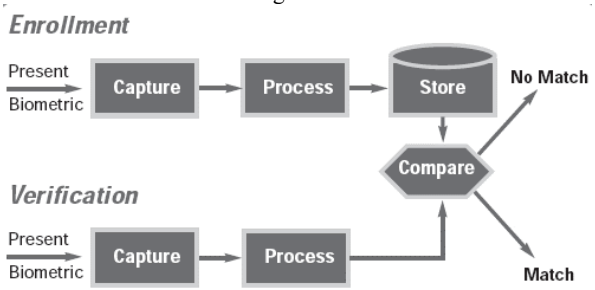

Fig. 14 : Block diagram of a typical biometric scheme for the iris recognition-III

A system can also be used in the verification mode as shown in the Fig. 14, where the biometric system authenticates a person's claimed identity from their previously enrolled pattern. In most computer access or network access environments, verification mode would be used. A user enters an account, user name, or inserts a token such as a smart card, but instead of entering a password, a simple touch with a finger or a glance at a camera is enough to authenticate the user.

V. CLASSIFICATION OF BIOMETRICS

Biometrics can be classified on the basis of physiological and behavioral characteristics of human beings.

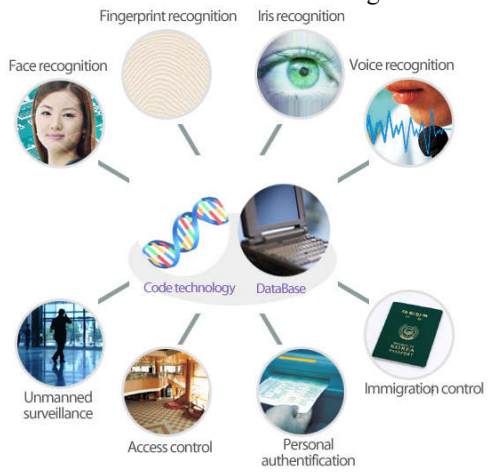

Fig. 15 : Biometric classification based on physiological & behavioural aspects-I

A typical physiological characteristic is a relatively stable physical feature of humans, such as finger print, DNA, password, hand, palm, signature, iris pattern, retina pattern or a facial feature & the respective photographic representation of the same is shown in the Fig. 15/16. Note that physical properties are the one which are examined by using the body shape.

A typical behavioral characteristic is a person's signature, keyboard typing pattern or a voice, card, RFID tag, Bar code, QR code, audio or a speech pattern of a human being & the respective photographic representation of the same is shown in the Fig. 15/16. Note that the behavioural are examined using the information of how person behaves which may include how the person makes his/her signatures, voice of a person and dynamics of keystroke.

Method	Coded pattern	Application
Iris recognition	Iris patterns	High security such as in airports, defense,…
Finger printing	Finger prints	Low security apps
Hand shape & size	Length & thickness of the hands	Low-security facilities
Facial recognition	Outline, shape & distribution of the eyes & nose	Low-security facilities
Signature	Shape of letters, writing order, pen pressure	Low-security facilities
Voice / Speech / Audio	Voice characteristics	Telephonic services
Retina	Nerve fibres	High security apps
Scan		
Palm	Palm print	Low security apps

Table 1 : Technology comparisons of various biometrics

The comparison of various physiological & behavioural types of biometrics applications is presented in Tables 1 & 2 respectively.

Biometrics	Universal	Unique	Performance	Acceptability	Potential to Fraud
Fingerprint	Medium	High	High	Medium	Low
Face	High	Low	Low	Low	Low
Signature	Low	Low	Low	High	High
Voice	Medium	Low	Low	High	High
DNA	High	High	High	Low	low
IRIS	High	High	High	Low	Low

Table 2 : Comparison of major biometric techniques

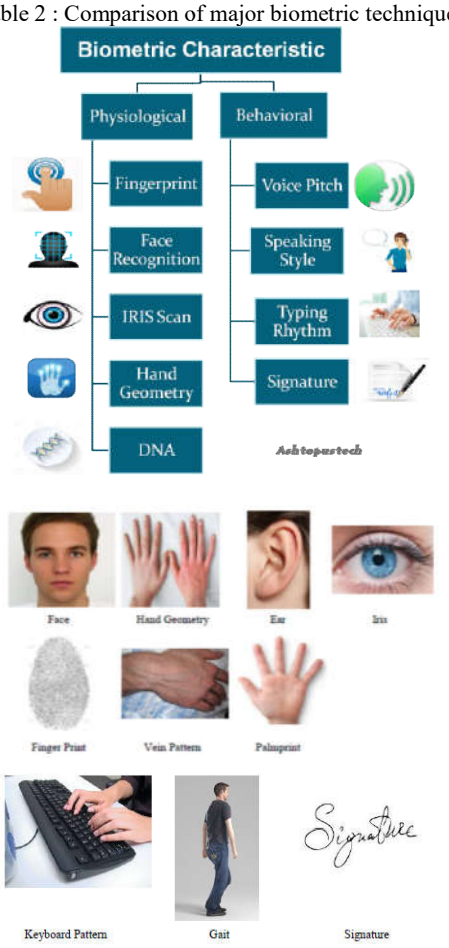

Fig. 16 : Biometric classification based on physiological & behavioural aspects-II

VI. BRIEF DESCRIPTION OF THE TYPES OF BIOMETRICS

There are different types of biometric techniques which are existing in the current scenario as mentioned in the section 5 & shown in Figs.15 & 16 respectively. A brief survey was made by some of the researchers amongst the various types of biometrics, which showed that amongst of all of them, the IRIS recognition took a major share and this is shown in the Fig. 17.

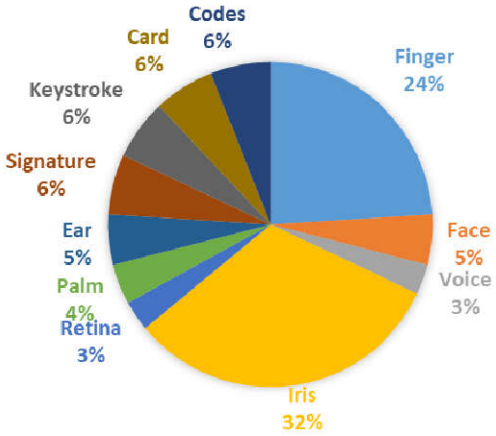

Fig. 17 : Effectivity of different types of biometrics

Each biometric identity has got its own advantage & dis-advantages and finally we ended up with the selection of the iris for the biometric identification of a human being because of a lot of advantages. Iris was selected as the biometric identity as it remains the same from the new born baby to the death of a person. Because of this, the iris is considered as the most strong biometrics method for person verification, with high stability, uniqueness, non-invasiveness and many other superior qualities. Some of the major types of biometrics are briefly discussed as follows one after the other with their advantages & dis-advantages.

A. Finger prints :

The patterns of friction ridges and valleys on an individual's fingertips are unique to that individual. For decades, law enforcement has been classifying and determining identity by matching key points of ridge endings and bifurcations. Fingerprints are unique for each finger of a person including identical twins. One of the most commercially available biometric technologies, fingerprint recognition devices for desktop and laptop access are now widely available from many different vendors at a low cost. With these devices, users no longer need to type the passwords – instead, only a touch provides instant access [refer Fig. 4/7/9/11/15/16].

B. Face Recognition :

The identification of a person by their facial image can be done in a number of different ways such as by capturing an image of the face in the visible spectrum using an inexpensive camera or by using the infrared patterns of facial heat emission. Facial recognition in visible light typically model key features from the central portion of a facial image. Using a wide assortment of cameras, the visible light systems extract features from the captured image(s) that do not change over time while avoiding superficial features such as facial expressions or hair. As facial recognition has got more amount of information, the computation time required for processing & identification using facial recognition is rarely used [refer Fig. 15 /11 / 15 / 16].

C. Speaker Recognition :

Speaker recognition uses the acoustic features of speech that have been found to differ between individuals. These acoustic patterns reflect both anatomy and learned behavioral patterns. This incorporation of learned patterns into the voice templates has earned speaker recognition its classification as a behavioral biometric.Speaker recognition systems employ three styles of spoken input: text-dependent, text-prompted and text independent. Most speaker verification applications use text-dependent input, which involves selection and enrollment of one or more voice passwords. Text-prompted input is used whenever there is concern of imposters. The various technologies used to process and store voiceprints include hidden Markov models, pattern matching algorithms, neural networks, matrix representation and decision trees [refer Fig. 6 / 15 / 16].

D. Retina Scan :

A retinal scan is a biometric technique that uses the unique patterns on a person's retina blood vessels. The human retina is a thin tissue composed of neural cells that is located in the posterior portion of the eye. Because of the complex structure of the capillaries that supply the retina with blood, each person's retina is unique. The network of blood vessels in the retina is not entirely genetically determined and thus even identical twins do not share a similar pattern. As the retina is present at the back of the eyes & getting the exact nerve pattern for identification will be very difficult and also needs more amount of information to be processed, the computation time required for processing & identification using facial recognition is rarely used [refer Fig. 3].

E. Signature Verification :

This technology uses the dynamic analysis of a signature to authenticate a person. The technology is based on measuring speed, pressure and angle used by the person when a signature is produced. One focus for this technology has been e-business applications and other applications where signature is an accepted method of personal authentication, but one of the major drawback of signature type of identification is, it can be forged [refer Fig. 16].

F. Passwords :

A password is a word or string of characters used for user recognition to prove identity or access approval to gain access to a resource (example: an access code is a type of password), which is to be kept secret from those not allowed access. The easier a password is for the owner to remember generally means it will be easier for an attacker to guess. However, passwords which are difficult to remember may also reduce the security of a system because :

(a) users might need to write down or electronically store the password,
(b) users will need frequent password resets and
(c) users are more likely to re-use the same password.
Similarly, the more stringent requirements for password strength, e.g., have a mix of uppercase and lowercase letters and digits or change it monthly, the greater the degree to which users will subvert the system. The major drawback of passwords is, it can easily hacked or known by the system administrator, hence it is not that much secured type of biometrics [refer Fig. 15 & 16].

G. Iris Recognition :

A major survey made across the world by some of the researchers (Fig. 7) showed that IRIS recognition is one of the powerful biometric recognition technique that could be used for the identification purposes. Iris recognition method uses the iris of the eye which is the colored area that surrounds the pupil and is unique for a particular human being. The iris patterns are obtained through video-based image acquisition system from a camera. Iris scanning devices have been used in personal recognition applications for several years for various applications. The technology works well in both verification and identification modes.
Out of all the numerous physical traits that are existing in the current biometric arena, irises are one of the more accurate physiological traits that can be used & has a large number of advantages over the others as it unique in nature for a particular person and cannot be forged or counterfeit. It has the benefits of being contactless and no preceding information from user's side is needed to start the usage of this method. A number of movies have used the iris scans for automatic recognition of human beings, such as I Origins (2014), Steven Spielberg's Minority Report (2002), The Island (2005), The Simpsons Movie (2007), The TV series Numbers & the Hollywood movie - Bruce Will's RED (2010) [refer Fig. 8 / 11 / 16], thus reveling the use of iris recognition even in the science fiction films.

VII. HUMAN EYE& ITS ANATOMY

An human eye is one of the most important organ in the human body and serves the vision, without which the whole world would be dark. The structure of human eye along with its parts is shown in the Fig. 18. The protective outer layer of the eye is called the sclera. The other components of the eye are cornea, lens, iris and retina. Iris of the human eye is generally elliptical in shape and located in the front end of the human eye surrounding the pupil. The optical elements of the eye focus the image onto the retina, thus initiating a series of chemical and electrical events within the retina. The sclera is the firm, outer, opaque and white subsequent layer of the eye. Sclera consists in conjunctive tissue, which is made of collagen and elastin fibers, and the sclera plays important role in the preservation of the three-dimensional structure of the eye and insertion points of the muscles which are responsible for the eye movement are also connected with it. In the next section, we briefly discuss about one of the important part of the eye, i.e., the iris, which is the topic of concern in our research.

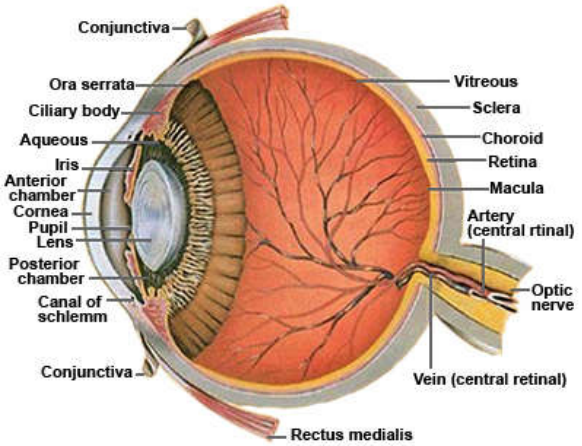

Fig. 18 : Anatomy of the eye

VIII. THE IRIS

The iris is one of the important part of the human eye. It is well blanketed from the encircling environment because it is an inner part of the eye, and its patterns are strong during the lifestyle. The iris is a skinny circular anatomical form in the attention and it is an annular part among black pupil and the white sclera, the iris contain variable sized hole referred to as pupil. It presents visible function denoted as the texture of the iris. The iris's characteristic is to manipulate the diameter and size of the pupil and therefore it controls the quantity of light that progresses to the retina.

The front view of the iris is shown in Fig. 19 to manipulate the amount of light getting into the eye, the muscular tissues associated with the iris (sphincter and dilator) either increase or agreement the centre aperture of the iris referred as the pupil. The iris includes 2 layers, viz., the pigmented the front fibro vascular known as stroma and below it are the pigmented epithelial cells. The stroma is attached to the sphincter muscle that is chargeable for the contraction of the pupil and moreover to the set of dilator muscular tissues, chargeable for the growth of the pupil which it does by way of pulling the iris radially.

The iris is broken up into 2 primary areas, i.e., the pupillary area, whose edges shape the boundary of the pupil and the ciliary place which constitutes the rest of the iris. The collarette is the thickest vicinity of the iris, maintaining aside the pupillary element from the ciliary issue.

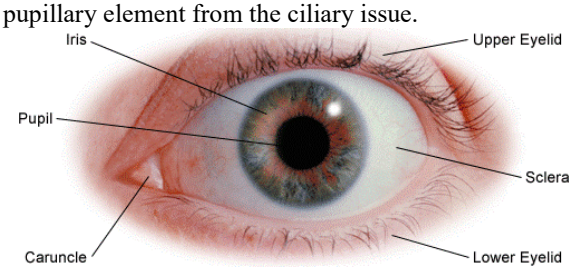

Fig. 19 : A front view of the human iris along with its different parts

Iris scans analyze the capabilities that exist within the colored tissue surrounding the pupil which has extra than 200 factors that may be used for evaluation, inclusive of earrings, furrows and freckles. The scans use a ordinary video camera fashion and may be achieved similarly away than a retinal scan. It will work via glasses and get in touch with lenses and in reality has the potential to create an accurate enough measurement.

The iris is a thin circular diaphragm, which lies between the cornea and the lens of the human eye. The iris is perforated close to its center by a circular aperture known as the pupil. In iris, its rich texture offers a strong biometric clue for recognizing individuals. Located just behind the cornea and in front of the lens, the iris uses the dilator and sphincter muscles that govern pupil size to control the amount of light that enters the eye. Near-infrared (NIR) images of the iris's anterior surface exhibit complex patterns that computer systems can use to recognize individuals. Because NIR lighting can penetrate the iris's surface, it can reveal the intricate texture details that are present even in dark-colored irises. The average diameter of the iris is 12 mm, and the pupil size can vary from 10% to 80% of the iris diameter.

The iris's textural complexity and its variation across eyes have led scientists to postulate that the iris is unique across individuals. Further, the iris is the only internal organ readily visible from the outside. Thus, unlike fingerprints or palm prints, environmental effects cannot easily alter its pattern. An iris recognition system uses pattern matching to compare two iris images and generate a match score that reflects their degree of similarity or dissimilarity.

The iris consists of a number of layers, viz., the lowest is the epithelium layer, which contains dense pigmentation cells. The stromal layer lies above the epithelium layer, and contains blood vessels, pigment cells and the two iris muscles. The density of stromal pigmentation determines the color of the iris. The externally visible surface of the multi-layered iris contains two zones, which often differ in color.

An outer ciliary zone and an inner papillary zone, and these two zones are divided by the collarets – which appears as a zigzag pattern. Formation of the iris begins during the third month of embryonic life. The unique pattern on the surface of the iris is formed during the first year of life, and pigmentation of the stroma takes place for the first few years.

Formation of the unique patterns of the iris is random and not related to any genetic factors. The only characteristic that is dependent on genetics is the pigmentation of the iris, which determines its color. Due to the epigenetic nature of iris patterns, the two eyes of an individual contain completely independent iris patterns, and identical twins possess uncorrelated iris patterns. The color of eye depends on the iris (bluish, pinkish white, brown, green, hazel, greyish, black, pigmented, etc…) pigment melanin's.

IX. HISTORY OF IRIS RECOGNITION TECHNOLOGY & ITS APPLICATIONS

The development of iris recognition technology dates back to the middle of the 20th century. In fact to say, the work started with the development of a recognition scheme by John Daugman, who was the father of the iris recognition. He developed and patented the first actual algorithms to perform iris recognition, published the first research 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. Adlerwrote, "*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 examine*d". 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 A. 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 some work in "Tableau de l' iris human". The definition 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. In fact, the word, 'IRIS' is derived from the Greek terminology, "*iridology*".

The core theoretical idea in Daugman's algorithms was 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 DOF 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 research paper, which many researchers even now are using it as the base paper. These algorithms became widely licensed through a series of companies, viz., 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.

With various improvements over the yester years, these algorithms remain today the basis of all significant public deployments of iris recognitions and they are consistently top performers in NIST tests (*implementations submitted by L-1*, *Morpho Trust 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 been 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, defense zones, sensitive areas, border areas, industrial sites, 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 10 UK airport terminals allowing frequent travelers 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 in many other countries across the world.

In the United Arab Emirates, all air, land, and naval sectors deployed 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 is enrolling the iris codes (as well as fingerprints) of all 1.5 billion citizens within 3 years for national ID and fraud prevention in entitlements distribution.

As of April 2016 the UIDAI (Unique Identification Authority of India) had enrolled more than 1 billion persons in this biometric programme. Iris is one of the 3 biometric identification technologies internationally standardized since 2006 by ICAO for use in *e*-passports (the other two are fingerprint and the face recognition ones).

X. IRIS RECOGNITION PROCESS

In this section, the process of iris recognition is presented in a nut-shell. Iris recognition is a method of biometric identification and recognition that uses mathematical sample-recognition strategies on images of one or each of the irises of a man or woman's eyes. Iris is a well-blanketed organ which is externally seen and whose epigenetic patterns are very particular and continue to be homogeneous structure. Its high area of expertise and balance makes it a great biometrics that may be used for figuring out the people.

These unique styles may be extracted by the usage of IP techniques hired on a digitized photograph of the human eye after which the consequences may be encoded right into a biometric template that could later be stored in a database for destiny comparisons.

Iris scanning takes advantage of random variations in the visible features of the iris, the colored part of the eye. The iris consists largely of a system of muscle that expand and contract the pupil in response to changing lighting conditions. The details of each iris are phenotypically unique, that is, no two are exactly alike, not even among twins, not even in your own two eyes. The structure of the iris develops in the embryo, assuming its lifelong character by the seventh or eighth month. Some color changes can occur in the first months of life, which explains why some babies who are born with blue eyes may end up with brown or some other color.

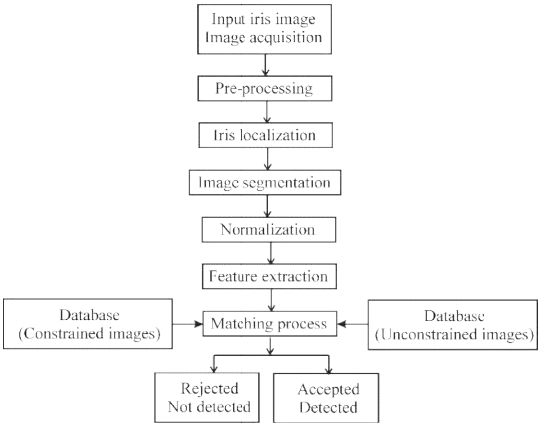

Fig. 20 : General flow-diagram of the biometric authentication process (DFD)

In fact, a typical iris recognition system consists of mainly 3 modules, viz., image acquisition, pre-processing stage as well as feature extraction and encoding (classification) & is shown in the form of a data flow diagram in Fig. 20 along with the block-diagrammatic representation is Fig. 21.

In the personal recognition technology process, recognition of iris is playing a lot of attention in the recent days in various work places. The technology of recognizing iris is an accurate technology amongst all the available technologies in the current scenario. If a person desires to be recognized by using the IRS, then first a digitized photo of their eye is produced from the camera, after which a biometric template is created for his or her iris area.

In this process of extracting the iris information from the digital eye representation, various IP techniques are applied and then the features are encoded into the biometric template and are stored in the iris database. The i/p biometric template (test pattern-human iris) is compared with all the other pre-existing templates inside the database & once the test pattern comes in front of the IRS, if the test pattern matches with the stored template in the database, then the identification of the person is a success, else it is unsuccessful. This comparison will be continued until the template which is matching is found, a decision is taken and the person is identified (accepted) or the template matching is found but the person is remained unidentified (rejected), which is shown in the Fig. 21.

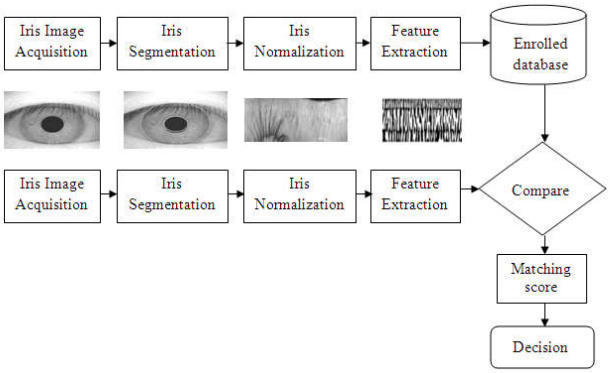

Fig. 21 : General biometric authentication process block diagram

It has to be noted in the context of our research work, the biometric recognition process has been worked out under critical conditions, which could be termed as under '*unconstrained environments*'.

XI. IRIS RECOGNITION UNDER CONSTRAINED ENVIRONMENTS

Iris recognition systems have gained a lot of importance in the modern day world. Lot of researchers have worked on the iris recognition under constrained environments, which means to say that there is proper illumination while capturing the photograph, there is no parallax, no shadows, there are no contact lenses or spectacles worn by the person, person to be looking towards the camera (orthogonal), images captured under ideal conditions within a proper focusing distance, images captured having good resolution, still images, eyes fully opened, focused image, noise free image, etc….

Due to specialized imaging conditions using near infra-red light, features in the Iris region are highly visible and there is good contrast between pupil, Iris and sclera regions & hence the image obtained would be sharp and recognition becomes very easy. Developing algorithms for the iris recognition systems under constrained environments is not a big issue as everything is proper, but the development of the iris recognition systems under unconstrained environments along with the analysis of its performance is still far from being perfect as extraction of the iris becomes very difficult, which is discussed in the next section.

XII. IRIS RECOGNITION UNDER UNCONSTRAINED ENVIRONMENTS

Iris recognition systems have made tremendous in-roads over the past decade, but work remains to improve their accuracy in environments characterized by unfavorable lighting, large stand-off distances, and moving subjects. One of iris recognition's major weaknesses is that it requires that the users be cooperative when making sure their eye is close enough to the camera and is enough for a high quality iris image to be collected. In fact, current commercial systems require an on-axis image of an eye, which is usually achieved through what may be called a "stop and stare" interface, in which a user must align in an orthogonal position to the camera. A large number of unconstrained iris images are shown in Fig. A1 in appendix. This makes it difficult or impossible for identification to occur if the image is taken under unconstrained environments such as

- non-orthogonal to the camera,
- bad/light illumination images,
- half opened eyes,
- image of eye captured from a long distance,
- occluded eye lids,
- blurred iris image,
- out of focus eye image,
- images captured on a move,
- wearing glass,
- titled iris,
- person looking at an angle,
- surgery done on the eyes (cataract),
- eyes affected with disease (glaucoma)
- squint eyes,
- non-ideal eye images,
- wearing contact lenses and also the
- orientation from an off-axis angle.

The main motto of our research work is to make use of such iris images taken under such unconstrained environments and to develop algorithms to correctly identify an individual when presented with unconstrained environments. One of the problems with non-orthogonal and light illuminated iris recognition is that when a person is not looking directly into the camera and when illumination has an effect on the image, the entire iris is not visible in the image. The effect of such iris images on the recognition performance has been the subject of great interest. It is generally believed that iris recognition performance should not vary greatly with such unconstrained iris images, as long as the sufficient iris data is available, but this is not verified in the formal evaluation.

Subset	CASIA-Iris -Interval	CASIA-Iris -Lamp	CASIA-Iris -Twins	CASIA-Iris -Distance	CASIA-Iris -Thousand	CASIA-Iris -Syn
Camera	close-up iris camera	OKI	OKI	long-range iris camera	IKEMB	IKEMB
No of Subjects	249	411	200	142	1000	1000
No of Classes	395	819	400	284	2000	1000
No of Images	2639	16,212	3183	2567	20000	10000
Resolution	320 × 280	640 × 480	640 × 480	2350 × 1750	640 × 480	640 × 480
Features	Cross section Iris Images	Non-Linear and Deformated	Twins Eyes	Long Range Images	Eyeglasses and Specular	Synthesized, modified, blurred, etc

Table 3 : CASIA Iris Data Set - Different unconstrained iris images

The work also focuses on the acquisition of light illuminated and non-orthogonal iris images, segmentation of such iris images using the basic techniques of segmentation, obtaining the sufficient data from the images and using matching algorithms for iris recognitions. Unconstrained iris images present in the standard database are used for our analysis purposes. One such unconstrained database is being presented in the form of a table as shown in table 3.

However, performance of iris recognition systems in unconstrained environments is still far from perfect. Iris localization, nonlinear normalization, occlusion segmentation, aliveness detection, large-scale identification and many other research issues all need further investigation. The success of investigations into such issues often depends on the availability of carefully designed iris image databases of sufficient size. Such publicly available datasets are however very limited.

Iris images when they are of 8 bit gray-level JPEG files, collected under near infrared illumination, recognition would become difficult. Like this, there are a lot of unconstrained parameters under which recognition of iris has to be carried out, which many researchers have not worked upon so far & is still in the developmental stage. This made us to start the research work on the iris recognition of humans under

unconstrained environments. The difference between the normal & unconstrained iris image is shown in the Table 4.

Parameter	Normal Images	Unconstrained Images
User behaviour	Cooperate	Less Cooperate
Working Distance	Close	long
Lighting	Near IR	Visible Light
Camera	Ordinary	High Resolution
Image Processing	Gray Image	Gray Image
Iris Segmentation	Regular Shape	Occlusion
Feature Matching	Direct	Optimized

Table 4 : Difference between normal and unconstrained Iris Images

XIII. Motivation & Problem Statement

In this section, the motivation that was obtained to take up the research work on the recognition of unconstrained iris images is being presented in a concise manner along with the problem definition. It is a well-known that that in the current modern technological world, biometrics plays a very important role in the identification of any human being (male/female) in any work-place. Various biometric techniques exists in the current scenario such as the Aadhar, finger-prints, palm, face, signature, symbols, retina, password, cards, cornea, head, nerve fibre, gait, signature, audio, code, cards, voice, speech, hand, etc… Each one has got its own advantage & dis-advantages and finally we ended up with the selection of the iris for the biometric identification of a human being as it has a vast number of add-on features. All the advantages, dis-advantages have been discussed in the previous sections in greater detail.

The technologies that exploit the biometrics have the potential for application to the identification and verification of individuals for controlling the access to secured areas or materials (defense / aerospace / space / industrial sector / educational). A wide variety of biometrics have been marshalled in support of this challenge as mentioned previously. Provided a highly cooperative operator, these approaches have the potential to provide acceptable performance in used properly. Unfortunately, from the human factors point of view, these methods are highly invasive.

Typically, the operator is required to make physical contact with a sensing device (*biometric identification system*) or otherwise take some special action. One possible alternative to these methods that has the potential to be less invasive is the automated face recognition. However, while automated face recognition is a topic of active research, the inherent difficulty of the problem might prevent widely applicable technologies from appearing in the near term. It requires huge amount of information for the analysis & detection purposes, it is quite computationally expensive and suffers from lot of drawbacks.

On the contrary, the finger prints can get worn out due to age, continuous work, etc… Similarly, the passwords can be hacked, stolen & re-used, hand gestures vary as the age passes and depends on the direction in which the hand is going to be scanned (requires huge amount of memory like the face), face of a human being goes on changing due to the ageing factor and hence the identification becomes a problem.

Automated iris recognition is yet another alternative for non-invasive verification and identification of people. Interestingly, the spatial patterns that are apparent in the human iris are highly distinctive to an individual. Like the face, the iris is an overt body that is available for remote (i.e., non-invasive) assessment. Unlike the human face, the variability in appearance of any one iris might be well enough constrained to make possible an automated recognition system based on currently available machine vision technologies. It has to be noted in this context that the iris is a part of the face & hence the iris recognition concept is the best method that could be used, also it is computationally less expensive because of lesser area (sub-set of the face).

Finally, to conclude, the biometric identification using iris has vast number of advantages over the others which are listed as below.

- Iris detection is one of the easiest method of biometric identity and recognition while also being one of the least invasive methods.
- It is of non-contact type.
- The iris has the specific characteristic of very little variant over a life's length yet a mess of variation among people.
- Irises are not only most effective, but differ between equal twins, however also among the left and proper eye, even DNA isn't precise amongst identical twins.
- Due to the masses of levels of freedom the iris offers and the potential to accurately measure the textured iris, the false take delivery of chance may be estimated at 1 in 10^{31} cases.
- Most of the currently deployed business algorithms for the iris recognition have a totally low fake attractiveness rate as compared to the alternative biometric identifiers.
- Replay assaults with the iris biometric can checked by detecting the liveness of the eye.
- The pupil changes its size while mild is shone into the attention.
- The algorithms are capable of measuring this variation in pupil size of the eye.
- The method of taking pictures of the iris photo isn't intrusive.
- Iris pictures may be computer matched & extra appropriately than a face photograph, and it's stated that iris recognition is extra correct than other biometric methods.

In the recent digital era of the current central government, biometric has been made compulsory in all the places (for ex., Aadhar, finger print & PAN). We had seen even though there were lot of biometric methodologies, each one was suffering from one or the other drawbacks. Finally, in this context after

studying the implications of each of the biometric methodologies, we arrived at the selection of the iris as the best method of biometric identification of human beings due to its large number of advantages.

Also, due to the current initiative taken up by the central government in the field of biometrics to be implemented in all sectors, this had further *motivated* us to take up the research work on the iris biometric field. The *main motivation* being some of the digital initiatives taken up by the government in the wake of security issues in the country. This has made us to *identify the problem.* Hence in continuation, with zeal of this research work after making a through survey, we are proposing some novel methodologies for the automatic recognition of biometric using iris by developing some software algorithms in Matlab/LabVIEW, the *problem* finally, being *defined* as the *research problem statement* as the "*Design and development of efficient algorithms for IRIS recognition system for different unconstrained environments*".

XIV. SCOPE OF THE RESEARCH WORK

The scope of the research work is presented in this section. The human biometric identification and recognition process has got a lot of applications in the daily life, staring from the domestic to the work places (banks, internet, industry, office, automobiles, educational sector, retail, defense, space, transportation, mobiles, computers, passports, etc…). Biometrics can be used in verification and in identification mode. In identification mode, biometric sample is taken for further recognition purpose and in verification mode the biometric system is used to authenticate the user's individuality. In this research work, the iris recognition system is used for personal identification as well as for the recognition purposes, thus serving the dual role.

Further, the scope of the research work is to develop couple of efficient algorithms for iris recognition under unconstrained environments in comparison with the existing ones using 2 types of tools, viz., Matlab & LabVIEW as majority of the people have worked under constrained environments and few of them have worked in the other case. Also, one application of the iris recognition system along with one hardware implementation was thought of during the course of the research work. The *major* scope of the proposed research work is mainly :

- To develop some efficient algorithms to overcome the security and recognition problems faced in many fields of works as mentioned above.
- To develop an iris recognition system to provide fast identification & recognition for all human beings and to work properly with all eyes of different sizes using different types of classifiers.
- To improve the performance of the commonly used existing algorithms.

XV. OBJECTIVES OF THE RESEARCH WORK

The main objectives of the research work is presented in brief in this section. The research work that is undertaken by me under the guidance of my supervisor is aimed to develop bio-medical image processing algorithms in Matlab/LabVIEW environments for the biometric identification of human beings through the IRIS part of the human eye under unconstrained environments. One of the main objective of the proposed challenge is to consider the drawbacks observed in the works done by the earlier researchers and to rectify the drawbacks observed in those works by developing some efficient algorithms for the automatic recognition of the unconstrained iris images of the humans. Drawbacks of some of the existing algorithms that are considered to be vital were decided on and work has been executed to overcome them by improving / enhancing the performance or by developing new algorithm/s by adding some additional parameters. Some of the *major objectives* that are being executed in our research work are

- Images are acquired from the CASIA & other databases (UPOL/UBIRIS).
- Conversion of the acquired image to gray scale.
- Pre-processing of the obtained iris image.
- Removing the effects of eyelids & other noises.
- Segmentation of the iris using different methodologies.
- Histogram equalization is then applied to adjust the contrast.
- Detection of major boundaries of the iris by using edge detectors.
- To reduce the false acceptance and false rejection rate.
- Normalization by using Daugman's & other methods.
- Extraction of features from iris and phase quantizing it to form feature vectors.
- Usage of different transforms for feature extraction.
- Classification of the feature templates using different types of classifiers.
- Matching of iris feature templates using different methods.
- To design an effective approach for individual identification of human iris for unconstrained images.
- To enhance modern existing algorithms to make the iris recognition more effective for unconstrained iris images.
- Basic performance assessment of proposed framework via evaluating the performance of iris recognition system using Matlab/LabVIEW.
- To develop an automated GUI for the iris recognition system using Matlab/LabVIEW.

XVI. OUTCOME OF THE RESEARCH WORK

The outcome of the research work is to show that when the designed algorithm/s developed in the Matlab/LabVIEW environment is run, the automatic recognition of the iris is done with minimum computational time in comparison with the work done by the other researchers till date taking into consideration many of the drawbacks of the fellow researchers, thus enhancing and improving the performance of the existing algorithms under unconstrained environments with the development of an automated GUI for iris recognition purposes.

XVII. Contributions of the Ph.D. thesis

In this section, the various contributions of the research work are presented below as 9 different entities with C1 to C6 done under Matlab environment & C7-C9 done under LabVIEW environment.

A. Contribution 1 :

Iris recognition using the concepts of Pre-processing, Segmentation (*Canny Edge Detection / Circular Hough Transforms*), Feature extraction (*Local Binary Pattern features Method*) & Classification (*Multi-SVM*) of iris images with the development of an automatic GUI using Matlab.

B. Contribution 2 :

Iris recognition using the concepts of Pre-processing, Segmentation (*Hough Transform & Canny Edge Detection*), Feature extraction (*Gabor Wavelets*) & Matching (*Hamming Distance*) of iris images with the development of an automatic GUI using Matlab.

C. Contribution 3 :

Iris recognition using the concepts of Pre-processing, Segmentation (*Fuzzy Trapezoidal & Sobel Operator Method*), Feature extraction (*1D Log Gabor Convolution Wavelet Method & Hybrid SVD Method*) & Matching (*Hausdroff Matching & Surf Matching*) of iris images with the development of an automatic GUI using Matlab.

D. Contribution 4 :

Iris recognition using the concepts of Pre-processing, Segmentation (*OTSU Algorithm*), Feature extraction (*SFTA Method*) & Classification (*Neural Network Algo*) of iris images with the development of an automatic GUI using Matlab.

E. Contribution 5 :

Iris recognition using the concepts of Pre-processing, Segmentation (*Morphological Operators*), Feature extraction (*GLCM Method & Fruit Fly with Cuckoo Search Algo - Heuristic Algo*) & Classification (*RBFNN, Neural Network & SVM*) of iris images with the development of an automatic GUI using Matlab.

F. Contribution 6 :

Iris recognition using the concepts of Pre-processing, Segmentation (*Canny Edge Detection Method & Hough Transforms*), Feature extraction (*Local Binary Pattern Method*) & matching of iris images (*Hamming Distance Method*) with the development of an automated GUI for iris biometric recognition using the Matlab tool.

G. Contribution 7 :

Iris recognition using the concepts of Pre-processing, Segmentation (*Boundary Detection Method using Sobel*), Feature extraction (*2D Gabor Wavelets & Haar Wavelets*) & Classification of iris images (*ANN Method*) with the development of an automated GUI for iris biometric recognition using the LabVIEW tool.

H. Contribution 8 :

Application of iris recognition system developed for electronic voting using LabVIEW.

I. Contribution 9 :

Hardware implementation of the iris recognition concept using ATMEL micro-controller interfaced with LabVIEW with the development of an automated GUI.

XVIII. Overall conclusions

In a nutshell, the purpose of carrying out the research work was to overcome the limitations of the works done by the various researchers on the biometric authentication using iris concept till date and to develop a fast biometric authentication system. The objectives that was set for the proposed research work have been met completely and the selected drawbacks had been overcomed by the way of comparison with the others. In this context, a highly effective iris biometric system/methodology has been developed incorporating a huge number of salient features. In the sense, the introduction to our research work is being presented. To conclude, a sincere attempt is being made to develop simple & efficient methods for iris recognition in "*unconstrained environments*" using a combination of several methodologies (hybrid algos) in the various process of the iris biometric recognition which could be seen from the results in the thesis report.

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