May-June2020
ISSN: 0193-4120Page No. 28571 - 28578

A Review of MRI Brain Print as Hidden Biometric

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Abstract

Biometrics is considered as a reliable source of authentication but sometimes they're vulnerable to forgery. Methods focused on traditional biometric traits such as fingerprints, face, hand geometry, iris, speech, signature etc. suffer from theft, imitator, and other privacy concerns. Biometrics offers a different level of protection, but it's not fool proof, we cannot use the same biometric trait again if once it is compromised. Hidden biometrics can be a smart choice, since they are hard to replicate. Hidden biometrics is a field where structural characteristics of hidden body parts are used to identify human subjects biometrically. We are finding the possibilities of using brain structure as biometric. People differ from each other in thoughts, learning abilities and other cognitive ability. Learning builds up the mind and accordingly in long course of time large scale structure is framed having sulcus and gyrus structures on surface of the brain. Their numbers, size and shapes are unique in a person. This paper intends to provide a comprehensive overview of the existing literature and insight on using MRI brain print as biometric. This offers an up-to - date review of using brain as biometric and its benefits.

Keywords:*Hidden Biometric, Structural characteristics, MRI Brain Print.*

I. Introduction

Conventional authentication mechanisms use hidden codes, keys or tokens and without much effort these can be duplicated or lost. It is mandatory to integrate biometric features into the framework to build a framework that guarantees more reliability, security and foolproof identification [22]. Biometric systems are extreamly important components in almost all safety areas and are considered the ultimate solution to the endless attempts at fraud, providing a secure way of authenticating and Identify person. A biometric recognition and conformation technique are utilizing physical or behavioural features of an individual to verify their personality. Biometric characteristics are unique to each human being, widely accepted, quickly captured non-intrusively, and often remain unchanged for life expectancy as a whole and identifiable without clear direction. Enrolment and authentication are the two main processes of a biometric verification system [23]. Biometric sample data are collected from a subject during enrolment, and the feature extractor gathers related information from the raw measurements, and that information is stored in the database. On the other hand, biometric information is discovered during authentication and compared against the database by means of pattern recognition techniques involving a feature extractor and a biometric matcher operating in cascades. Mainly there are two types of biometrics- Behavioural biometrics that typically tests the traits that they automatically accumulate over a time span. Like voice expression study, analysing signature dynamics or measuring the

May-June2020
ISSN: 0193-4120Page No. 28571 - 28578

time spacing of typed words. Physical biometrics measures the built-in physical attributes on an individual. Like studying patterns of fingertips, measuring facial characteristics, measuring the shape of the hand, analysing features of coloured ring of the eye, analysing blood vessels in the eye, analysing vein patterns etc.

In commercial biometric system fingerprints, face, and iris are currently among the most widely used physiological traits. Behavioural characteristics such as keystroke patterns, gait and analysing signature dynamics are attractive, but are considered poor because of their lack of distinctive features and durability. Behavioural and Physical biometrics also known as extrinsic biometrics as they are visible to all. It seems to be superficially stable. After all, it always belongs to us. But we can’t avoid the fact that they are prone to forgery. We reveal our face, fingerprint and voice in our day to day life through interactions which we have knowingly or unknowingly with others. Thus, for applications that are critical and require more confidentiality, it is therefore necessary to switch to hidden biometric [24]. It is also known as intrinsic biometrics as we will use the intrinsic traits of the body like brain print, veins, retina, chest print, bone print etc. These features are not readily accessible and can certainly not be imitated. Our focus in this paper is on using brain print as biometric trait. The real identity of humans is brain. So why not use brain for biometric purposes. The advantage is that neither the brain can be changed by the subject nor it tends to be replicated by another person therefore this personality is constantly certifiable.

II. The Brain

The brain is the most important organ of the nervous system, and the human body's most essential and vital organ. It is composed of over 100 billion nerves, which interact through trillions of connections known as synapses. Even when different brains can be identical and have common characteristics, scientists have concluded that no two brains are or ever will be the same [4]. Human brain which is exception in its design and capabilities and almost seem like work of an extra ordinarily brilliance and it is unique because development of this human brain is impacted by genes, what we inherit and experiences that we go through and what we learn from these experiences. Some research may argue that grey matter will change with age or because of disease but it is known to show steadiness in adulthood [5, 6]. The microstructure of the brain may not be stable in this short period of life but the macro structure of the brain in the form of gyrus and sulcus is fully stable. The brain is divided into two halves- The right halves (hemisphere) and the left halve (hemisphere) and both this halve are connected to each other by a bundle of nerve fibre is known as corpus callosum. A brain has wrinkles on its exterior surface and this wrinkly part is known as cerebrum, which makes up the major of the brain. Cerebral function is responsible for many higher neural functions such as memory (intelligence), emotions and consciousness.

The cerebrum is covered by a continuous layer of grey matter that wraps around either side of the forebrain is known as the cerebral cortex. This thin, vast area of wrinkled grey matter is responsible for the greater functions of the nervous system. The ridge of one of those wrinkles is a gyrus and the groove between two gyri is a sulcus. The shape of such tissue folds shows different regions of the cerebral cortex. The gyrus is distributed among the grey matter and white matter. The composition of each brain's grey matter is peculiar, and it is unaffected to noise and objects from acquisitions [28]. To identify an individual, we can differentiate with respect to brain’s grey matter. Thus, for this first of all we have to capture the brain image. There are major advances in different methods for neuroimaging, For example, positron emission tomography (PET), computed tomography (CT), electroencephalography (EEG) and magnetic resonance imaging (MRI).The brain is pictured in MRI and CT scans as a dense mass attributable to multiple neurons, grey matter and white matter.

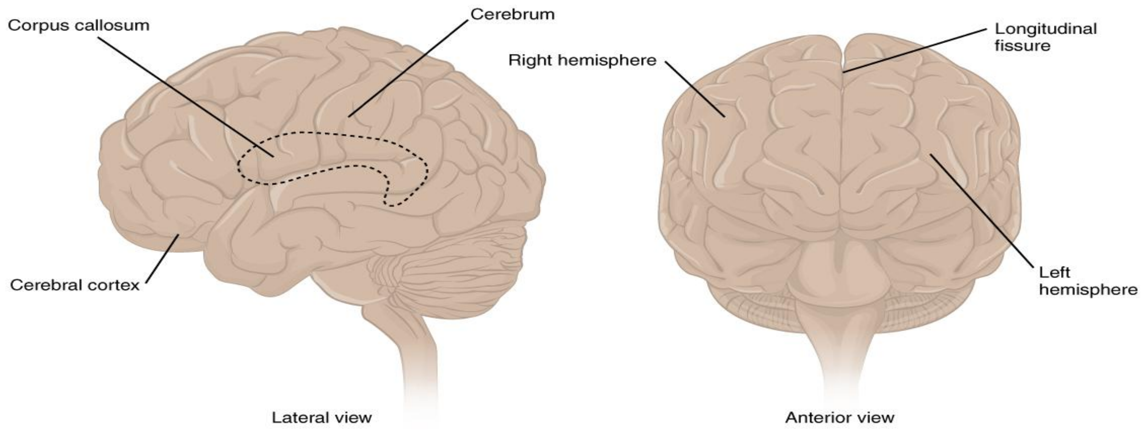


Fig. 1. The Cerebrim

III. Literature Survey

Traditional biometrics, such as iris, fingerprints, images, speech, and DNA, have been extensively studied in literature, and widely implemented in real-life cases at present. Yet each one of these biometric traits has its own weaknesses. Actually, these conventional biometric characteristics are very easy to access. Like unintentionally we leave our DNA sample wherever we go in form of hairs, saliva, flakes of skin, drops of blood etc. Fingerprints can be manipulated by a 2D image of a fingerprint produced by a standard inkjet printer [21] and also by high-resolution photography [1] by plastic moulds, latex milk, and wood glue [7]. Our images are stored on various social media platform which is open to all. While we are talking who is recording us, we don't know. All these conventional biometric characteristics are open and cannot be replaced if once get forged. Therefore, a biometric safer than these conventional biometric would fulfill two requirements. First - stealing would not be easier and second – it should not be open (visible). Hidden biometric fulfill these requirements It can be defined as a special class of biometrics in which the purpose is to consider a person's physical or behavioural characteristics which are not openly visible. It uses information which is normally used in the clinical field. With regard to spoofing such techniques are efficient. Reshmi et al., 2016 and Qiong Gui et al., 2019 [8, 25] shown comparison between brain biometrics with respect to the seven biometric identifiers described by Jain et al [9], comparison is shown in Table 1. Wachinger, et al. 2015 attempted to identify individuals with respect to neuroanatomical traits. For this also a broad dataset of MRI brain scans were utilized from public brain repositories and created a new mathematical method for anatomical data structure analysis. As a result they constructed a Brain print and 99.8 percent has been achieved in terms of accuracy to identify the individuals based on the MRI scans [17].

Here we are reviewing human brain images obtained from MRI. Our aim is to evaluate if human brain images can be used for authentication purpose. These images provide details about folds, including a series of cortical and subcortical structures. The brain code / brain print is created by gyrus and sulcus patterns. Brain growth in the skull gives a unique characteristic. Several studies have answered the question of the origin of brain folds in this sense Van Essen, 1997 and Régis et al., 2005 concluded that both the mechanical tension which occurs during growth of brain and the experience what we learn allow the cortical and subcortical patterns to develop differently [10,11]. Brain development is not same even for the identical twins as described by recently discovered Jumping genes [2]. Wachinger, et al. 2015; Dubois & Adolphs, 2016, Finn et al., 2017; Valizadeh, et al. 2018, according to their research studies it can be concluded that the anatomy of the human brain is unique [17-20]. Few researchers tried the possibility of using brain codes as biometric trait by two possible approaches; first approach is based on texture analysis and second approach is based on shape and structure analysis. With respect to texture analysis Aloui et al. [26] used a single slice from a volumetric image of an MR. Specifically, they extracted textural features, using 1D Log-Gabor

May-June2020
ISSN: 0193-4120Page No. 28571 - 28578

transform from 2D images that contain cortical folds. Using a similar algorithm to the one used for iris recognition by Daugman, in 1985 [12], a binary template was developed which they used as a brain code. They did verification of the brain code by using Hamming distance. The key downside of this method is that at the time of matching only one MR slice is captured at a given distance this can impact output result which may be less reliable descriptors.

With respect to shape and structure analysis Aloui et al. [13,27] captured shape information from a set of cortical and subcortical structures and used only one slice of a volumetric image from an MR. Specifically, brain shape descriptors are captured from an ellipse that delimit the brain. Later, they created a features vector expressing the brain shape.

A range normalized Euclidean distance was used for verification for calculation of similarity. Chen et al. [14] in 2014 introduced an algorithm for brain segmentation to capture grey matter from an input brain image. Then, a matching algorithm based on alignment was developed for brain code verification. Takao et al. [15] in 2015 used voxel-based morphometric approach to normalize the images and to perform brain recognition.

They did feature extraction using principal component analysis. For verification they used Euclidean distance between image pair.

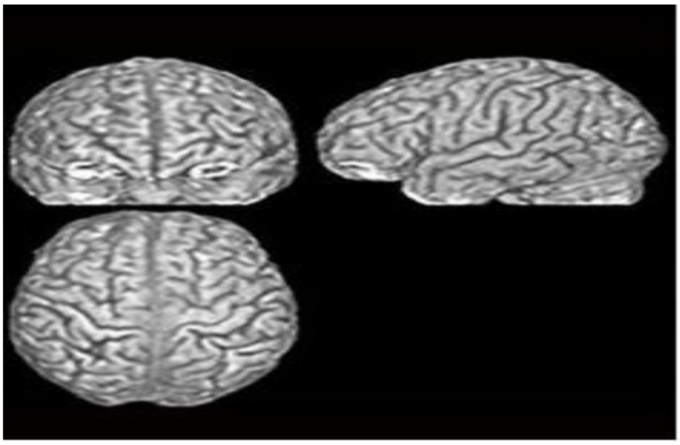
Table 1: Comparison between brain and other biomatric traits.

Identifier	Universality	Uniqueness	Permanence	Collectability	Performance	Acceptability	Circumvention
Fingerprint	Medium	High	High	Medium	High	Medium	Medium
Face	High	Low	Medium	High	Low	High	High
Voice	Medium	Low	Low	Medium	Low	High	High
Retina	High	High	Medium	Low	High	Low	Low
Iris	High	High	High	Medium	High	Low	Low
Brain	High	High	High	High	High	Medium	High

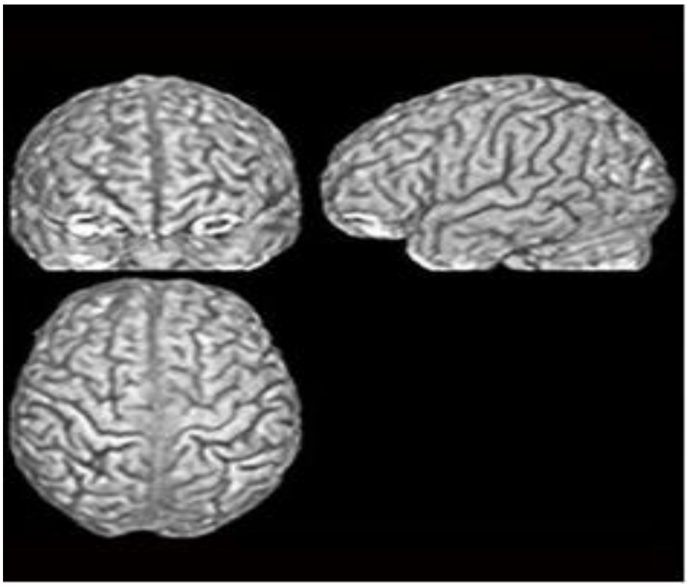
IV. Brain MRI

Many diagnostic procedures such as imaging using Computed Tomography (CT) or Magnetic resonance imaging (MRI) are used to reach certain unseen features of human brain. Several imaging devices are able to generate very specific 3D anatomical details about the subject. MRI is one of those imaging devices.It uses magnetism, radio waves and a computer to generate images of the subject. It is commonly used in diagnosis because of its good quality of spatial resolution and high efficiency in discriminating between soft tissues. There are no ionized radiations in this, thus it is undoubtedly a good choice for a biometric modality. In this paper the biometrics based on brain MRI (Magnetic resonance imaging) are given special interest. MRI has been around since the early 1990s and has been used in medical brain investigation ever since [16].This is due tozero radiation and high resolution quality. This developed quickly and became one of the most important techniques for brain imaging. Currently available technologies are expensive and does not seem financially viable option but in this paper we want to explore the possibility of these approaches hoping that future will bring more cost effective and compact imaging technologies which can be utilized in biometric application for authentication purpose.

Same as fingerprints, no two individuals have the same anatomy of the brain, a study by University of Zurich researchers has shown [3]. This singularity is the product of a mixture of genetic factors and experiences of human life. As shown in fig 2 image a and image b belongs to twins. For every individual the furrows and ridges are unique. MRI offers a total 3D image view of entire internal brain structures. One can easily differentiate between them, visually, we can analyse the texture and capture MR volumetric image slice by applying suitable image processing algorithm which can be used as a brain print.



a.



b.

Fig 2. Brain scans from the front, side and above of two different persons(a) Person 1, (b) Person 2.

V. Brain Print as Biometric Trait

Brain is the most complex of all but one of the essential organ in the human body. It is known to be a human being's identity, as it controls much of the body's behavioural functioning. It is a vital part of our body. Entire body's organs and its functions is controlled by brain. Since each individual has a unique behaviour, implying that behavior controlling organ should also be unique. The identity of a person is due to his / her brain. Thus, we say brain prints could be used as biometric traits. Brain biometrics are used for long periods of time, but in the form EEG where brain activity can be measured either by monitoring blood flow within the brain or by evaluating electrical signals of the neurons. Aloui et al. [13] proposed a model using 3D MRI curvilinear slices along with Gabor features extraction and ACP dimensionality reduction to generate brain template and 99.64 percent has been achieved in terms of accuracy. Accuracy can be further increase to reach 100% when combined with the results obtained by other modalities by using fusion techniques. This rate can be increased by combining brain feature with the corresponding face features.Fig.3 describes the genericsystem architecture for using MR brain image brain print as an identification signature for an individual. Steps are as follows -

1. Pre-processing

- Skull stripping is an initial step with an aim to extract non-brain tissue from MR brain images for further studies. Its precision and speed are seen as major elements in the segmentation and evaluation of the brain image. Various skull stripping methods are present according to their pros and cons they can be selected for experiment purpose.
- Histogram Equalization - It is a method to enhance the dynamic range and image information by modifying the image in such a way that it has a desired structure.
- Slice Extraction- Using appropriate method brain image slice will be extracted.

May-June2020
ISSN: 0193-4120Page No. 28571 - 28578

2. Brain Image Segmentation

This is very important step as it involves obtaining the brain tissues from the extracted brain image slice with noise reduction. Image segmentation will be performed in such a way that in preserves edges. Various segmentation methods are available in the literature for example elliptical evaluation or slicing.

3. ROI Extraction

Region of Interest (ROI) plays an essential role in selecting the interesting pattern from segmented brain image. Each image has different gyrus and sulcus structural patterns. ROI selection should be such that it captures all the important information.

4. Brain Image Normalization

It is used to improve the image configuration by preserving clarity and contrast of brain image.

5. Feature Extraction

Features are nothing but the brain image characteristics which provides the necessary information required for further processing. There can be different kinds of features present in the MR brain image like colour-based, texture-based and shape-based etc.

The features extracted from the MR brain images is what's named as Brain Print and stored in a database. This will be used as an identification signature for an individual.

VI. Conclusion

The biggest downside of the prevalent biometrics is their vulnerability to forgeries. For the future, the hidden biometrics can be seen as an appropriate solution for overcoming this restriction. In this paper, we presented a review on the use of MRI brain print as a hidden biometric identifier, which has some specific traits and advantages over prevalent biometrics and thus getting researcher's attention. Other imaging techniques such as X-ray and CT are harmful for body, safety issues should be taken seriously about number of times it can be used. On the other hand, MRI is undoubtedly a good choice for a biometric modality as it produces internal images with high resolution. We surveyed literature and concluded that brain biometric is the most secure and relevant biometric method and more stable than brain signals. Brain structures can be used for biometrics as 2D slices or 3D volumetric data, with structural transformation such as number of curves, measurements of

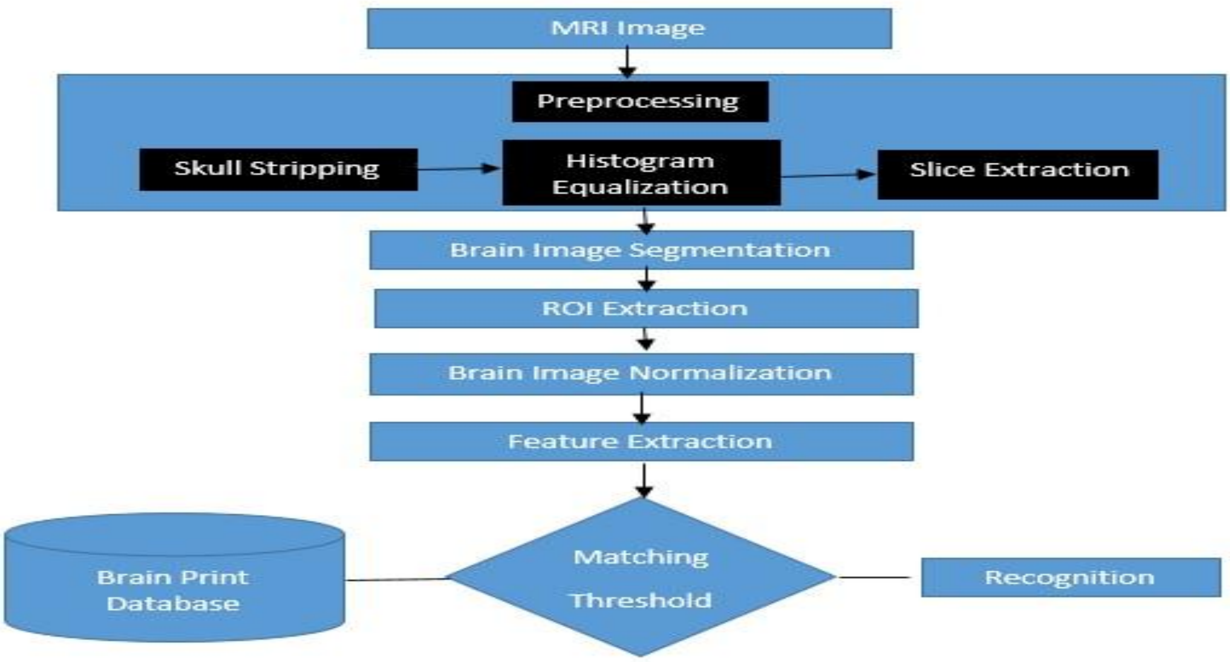


Fig 3 Generic system architecture

curvatures, brain prints and transformation of brain prints. Practical biometrics require real-time brain imaging techniques. We believe brain as hidden biometrics can give another level of security which can be fool proof and best for the application which are critical and require more security.

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