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Intelligent Integration and Fusion of Multimodal Biometric Systems

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Abstract: The propagation and the frightening expansion of frauds due essentially to the easy access to high technologies make it difficult or sometimes impossible to detect these frauds and impostures. Therefore, it has become important, if not urgent, to develop identification techniques and tools that are more robust to attacks, more precise and more efficient. There are currently in Europe and some American countries very efficient biometric systems that combine two (2) modalities (photos and fingerprints in the case of biometric passports), but they remain very vulnerable, notably because of acquisition problems, data quality or the non-permanence of certain biometrics. Therefore, the systems based on biometric modality has been growing in the world for a decade. The processes of identification and identity verification of individuals have a very wide spectrum of applications in modern society and are becoming very relevant. However, the field of multi-biometrics is not new, many researchers have been working on this topic especially in the last 10 years. Scholar Google lists nearly 6000 publications on the subject, half of which since 2018. Real systems are in production, we can cite the UID program in India to enroll the 1.300 billion inhabitants with the 10 fingerprints and the two Iris. Most of the techniques consisted in generalizing classical biometric systems (with one modality) by attribute fusion (concatenation of data, statistical reduction...), by score fusion (often performed by summing up the comparison scores from each biometric system) or by decision fusion (majority vote most often). The objective of our work is to propose new techniques of fusion & multimodal biometric integration by using artificial intelligence tools and especially the application of fusion techniques such as: Brute Force Search, Support Vector Machines, neural networks, fuzzy systems, neuro-fuzzy systems, Genetic Algorithms, Particle Swarm Optimization.

Keywords: Biometric, Artificial intelligence, Pattern recognition, Image processing

Introduction

Europe and some American countries currently have high-performance biometric systems that combine two (2) modalities (photos and fingerprints in the case of biometric passports), but they remain highly vulnerable, notably due to acquisition problems, data quality or the non-permanence of certain biometrics. In our country-Algeria-, where the application of biometrics is taking its first steps, it remains primary because of a single modality (in fact, two modalities are taken, face and fingerprint, but only one modality is used (fingerprint or photo) during verification). This is highly inadequate and certainly very vulnerable. Through this paper, we hope to convince local and national authorities to opt for multimodal fusion for better performance. There's no doubt that the security and economic impact will be immense, translating into better control and mastery of

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information on the security front. Nevertheless, other logistical aspects must imperatively follow: a robust, uniform national network linking all the country's relevant institutions, where citizen databases must be distributed, as well as the associated real-time applications that must follow (wireless devices, GSM, distributed d-bases...).

In another part of view, some of the limitations imposed by single-modal biometric systems, can be overcome by employing multiple biometric modalities (such as than a person's face and fingerprint or several fingers of a nobody). Such systems, known as multi-biometric systems modals, are expected to be more reliable due to the presence of multiple modalities biometrics (Hong et al., 1999). By asking the user to present a sub-random set of biometric traits (e.g. left index and fingers right means, in that order), the system ensures that a user is indeed present at the time of data acquisition. These systems can also meet the stringent performance requirements imposed by various apps. Multi-modal biometric systems address the problem of non-universality, since several features ensure sufficient coverage of the population (Jain et al., 2004), and they improve the precision of the comparison (Jain et al., 2005). In addition, multi-modal biometric systems provide anti-parody measures by making it difficult for an intruder to simultaneously mystify the multiple biometric traits of a legitimate user. Hence, the development of biometric systems based on multiple biometric traits a received considerable attention from researchers.

Modes of Operation

A multi-modal biometric system can operate in one of three different modes: serial mode, parallel mode and hierarchical mode. In fashion serial operation, the output of a biometric trait is typically used to reduce the number of possible identities before the next trait is used. This serves as an indexing scheme in an identification system. For example, a multi-modal biometric system using face and fingerprints could employ face information to search for the few best matches then use fingerprint information to converge on a single identity. It is contrary to a mode of parallel operation, where information from multiple traits is used simultaneously to run recognition. This difference is crucial. In the serial operational mode, the different biometric characteristics do not have to be acquired simultaneously. Moreover, a decision could be reached without acquisition of all traits. This reduces the overall recognition time. In the hierarchical mode, classifiers are combined in a structure tree.

Fusion in Multi-Modal Biometric Systems

A biometric system has four important modules. The sensor acquires the biometric data of the user; the extraction module extracts a set of characteristics from acquired data; the compare or the match module compares the characteristics acquired with the models stored in the database, for example, using a classifier or a comparison algorithm; the module decision-making uses the result of the previous module either to identify a person already registered or verify the identity of a person. Sanderson and other researchers (Sanderson & Paliwal, 2002) have classified fusion or the integration of information in biometric systems in two broad categories:

– The Fusion in Pre-Classification.
– Post-Classification Fusion.

Fusion or integration in pre-classification refers to merging information before the application of any classification algorithm or comparison. In post-classification integration the information is merged after the classifiers' decisions have been obtained.

State of the Art

The multi-modal approach integrating the biometric characteristics of an individual is a relatively recent field of research. Indeed, the first publications date back to 1995. This work had been carried out by Brunelli and Falavigna (Brunelli et al., 1995) who used the multi-modal approach for the identification some people. Their system consisted of two image and audio subsystems, consisting respectively of two and three classifiers, These classifiers were non-homogeneous and their outputs were then integrated after normalization. The resulting multi-modal system had a recognition rate of 98% whereas mono-modal audio sub-systems 2 and image had recognition rates 88% and 91% respectively. Duc and his team (Duc et al., 1997a) have developed a technique for merging biometric information for the authentication of persons also based on the integration of two image and audio subsystems called experts. The novelty of this technique compared to the previous one was that it allowed to evaluate the bias provided by each sub-module and this bias was then used to calibrate and reconcile the decisions made by each subsystem. They then managed to reduce the error rate and obtain a good recognition rate of 95.50%. We should also mention the work of Jourlin and his colleagues (Jourlin et al., 1997), which also focused on the fusion or multi-modal integration of features. Here, it is a question of verification as well. They take over the ideas suggested by Dieckmann's team in 1997, as Duc indicates in his article (Duc et al, 1997b), according to which, it is possible to achieve multi-modal recognition by merging or combining audio characteristics and visual information of the contour of the face during the production process of facial expression. The resulting audio subsystem had an FA3 of 2.3% and an FR4 of 2.8%, for a recognition of 97.2%. The image system had an FA of 3.0% and a FR of 27.8%, for a recognition of 72.2%. After Merging of scores, the resulting system achieves an FA of 0.5%, an FR of 2.8% and a 96.60% recognition.

In all these studies, we notice that the multi-modal system consists of the fusion of two or three uni-modal subsystems. Without losing sight of the specificity of each subsystem involved, we will say that the multi-modal systems designed in this way are distinguished from each other by the fusion technique employee. This combination is thus done using a neural network in the case of Brunelli and Falavigna (1995), of a classifier bayesian in that of Duc (Duc et al. 1997a, 1997b), then finally of a weighted sum of the similarity scores in the Jourlin case (Jourlin et al.,1997), where the weights are obtained using a dichotomous algorithm. In all the cases, the multi-modal system has performances superior to those of each unimodal subsystem. Jourlin and his teammates use a variant of component analysis main derivative of the technique initiated by Turk and Pentland, developed in 1991. In this original version, the authors identify images of whole faces. For their experiments Turk and Pentland use faces (pictures) of size variable, taken with different lighting, sometimes with the head more or less leaning. The system then proves to be insensitive to changes in lighting with 96% correct recognition, somewhat sensitive to orientation change with 85% correct recognition and finally they get a rate of 64% recognition, following a variation in the size of the image of the face. By Compared to Brunelli and Falavigna, the performance of component analysis (ACP) are slightly higher. Compared to the work of Duc et al. (1997) Turk and Pentland's approach is much simpler mathematically, it consists of locating the corners in the input images (face, iris, and fingerprint) by applying the Harris operator (Morin, 2006). The latter is based on the contrast, i.e. at each change of contrast we consider the point as a corner, and we recover its coordinates (x and y). At the end of this step we will have a vector of points. It is therefore this technique that we will use in the extraction module of the features of our system. Consequently, very few researchers have studied the integration or combination at level of characteristics and most of them generally prefer plans of fusion in post-classification (Ross & Govindarajan, 2005; Adjoudj, 2022).

Fusion Approach Developed

In this section we will describe the approach developed for the automatic multi-modal biometric recognition of people based on the fusion of their biometric characteristics which are: the face, the iris, and the fingerprint. For this, two methods have been developed; the first is a method classic based on notions of calculating distances (Fig 2), while the second is an approach based on the use of neural networks for classification (Fig.3.b). A complete and detailed description of the two approaches will be presented in the following sections, as well as a comparative study between them. For the validation of our two methods, we tested them on two databases. Data called MIT and CMU (see next section).

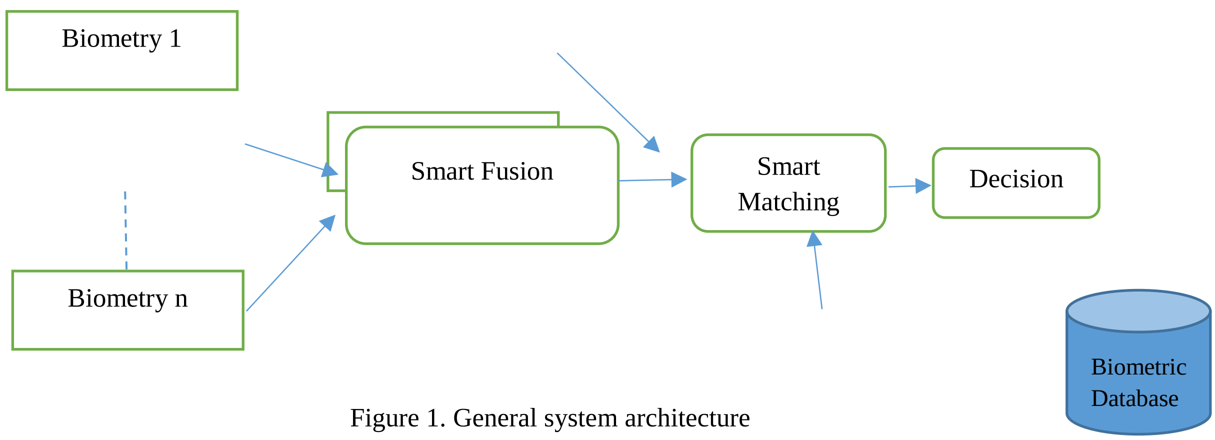

Figure 1. General system architecture

As previously said, the multi-modal biometric fusion approach consists of automatically and reliably recognize a person. By presenting his three biometric characteristics such as Input Data (face, iris, fingerprint, plus an identity in the case of verification), the result of the system will be either the validation or rejection of the proclaimed identity (in the case of a verification) or its identity, if it is already registered in the database (in the case of a identification). see Fig.1.

Developed Multi-modal Biometric Fusion System

Like any biometric system, our system is composed of the main modules which are:

– The feature extraction module (we used an operator called Harris) (Morin, 2006), (Adjoudj, 2006),
– The comparison module (Matching), two methods were used, the geometric first and which is the Euclidean distance (used especially in classical approach), the second is a neural network used for the classification (neural approach),
– And the decision module.

With only one exception which is the first module of a biometric system (the sensor). For our system (see Fig.2), we have the images ready to use.

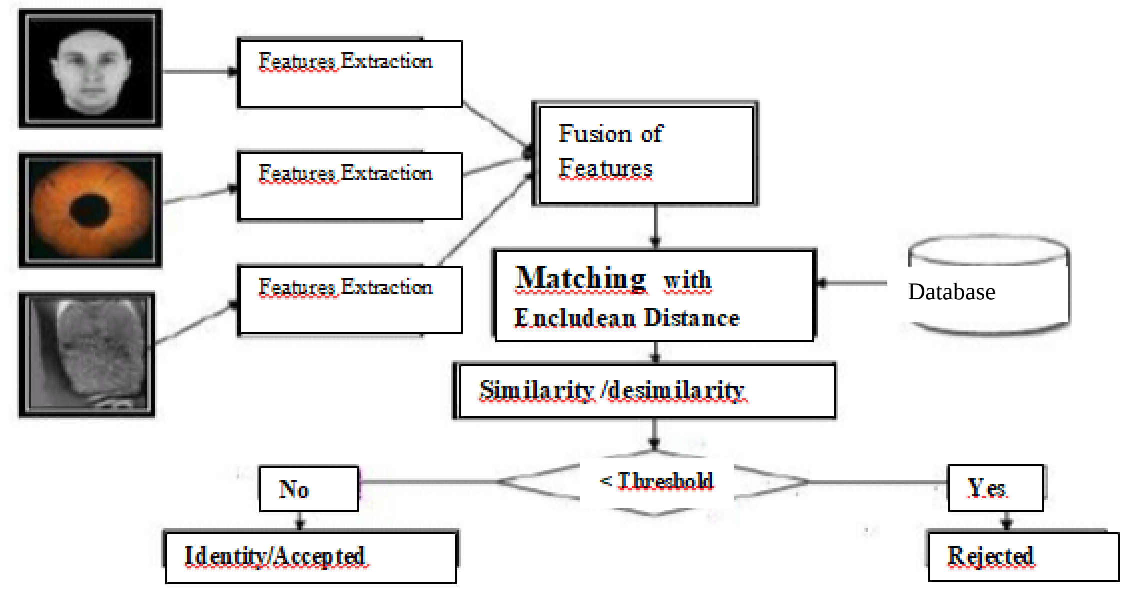

Figure 2. Schema of our system.

The Smart Distance-Based Multi-Modal Biometric Fusion Approach

The multi-modal biometric approach that will be described in this section is an approach based on the calculation of the Euclidean distance between the combined footprint/ merged (the fingerprint that we will have as a result after the integration of the three fingerprints: the face print, the iris print, and the fingerprint) of the input person, i.e. the person to be identified and all the combined fingerprints of all individuals in the database. So the person to be identified corresponds to the person in the base who has the maximum number of points similar. First of all, the system must extract useful information, i.e. locate only the points (features) in the input images, then it must construct a single vector from the three vectors obtained during the phase previous one (by a simple concatenation), and compare the latter with others which already exist in the database, if these vectors look alike then the person is identified (recognized). Algorithm shows the operation of this approach.

Smart Algorithm

Propose new techniques for multimodal biometric fusion using artificial intelligence tools.
1)- Implement independent biometric information pre-processing processes (biometric data quality):
2)- Acquisition, filtering, features extraction
3)- normalization methods (UCN Unconstrained Cohort Normalization), Min_max , etc....)

4)- application of fusion techniques: Brute Force Search, Support Vector Machines, neural networks, fuzzy systems, neuro-fuzzy systems, Genetic Algorithms, Particle Swarm Optimization ....
5)- Securing acquired data.
6)- Generalization of BioHashing.
7)- Comparison of multi-biometric data.
8)- Consideration of biometric data quality.
9)- In general, performance is analyzed using measures derived from international standardization (such as the Error Equal Rate or EER).

Fusion Step

The integration of multiple biometric modalities, or so-called multimodal systems (Ayesha et al., 2020), improves recognition efficiency. The multi-view face and fingerprint modalities were combined in this work to create the multi-view multimodal biometric framework using score-level fusion. The combination at the score level provides a perfect balance between data availability and ease of execution. The decision level indicates the insertion of a similarity matrix for all combined scores. If the application has a high score, the system must approve it (high number interest point pair).

Our research focused on parameters associated with frequency. The rationale behind selecting such parameters is based on their ability to enable the representation of the fingerprint through a fixed-size vector. The definition of this characteristic is necessary for the purpose of comparing two Bio codes and verifying their level of similarity or dissimilarity. The aforementioned comparisons suggest that there exists a fluctuating level of dependability, which may ultimately lead to the acceptance or rejection of certain practices. The Euclidean distance method is employed as a comparative technique (see next section).

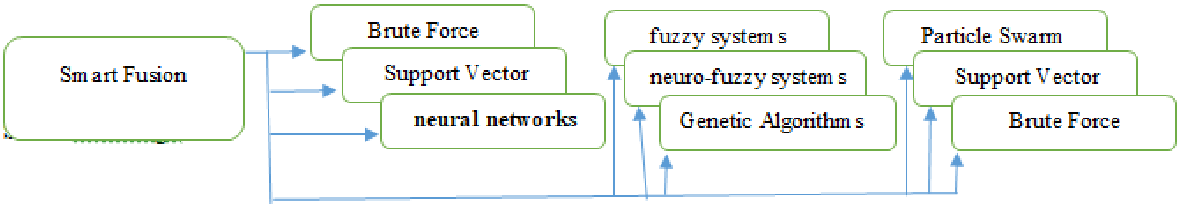

Figure 3.a. – Deferents approaches of smart fusion schema

Smart Matching Step

Matching is the core of this system, and it is the comparison of the vector merged from the input person (constructed in the previous step) with those from the database. This comparison is based on the calculation of the smart distance, so we need to measure the similarity between two individual vectors V_1 & V_2. Two individuals will be said to be close if they have roughly the same values variables. In general, the smart distance is used. Denoted d, it is defined as the root of the sum of the squares of the differences of the coordinates x_i, y_i, according to the formula described in [1], and as we have already used it in (Adjoudj, 2022), see Fig.2.

$$d(V_1,V_2)=\sqrt{\sum_{i=1}^{p}(x_{1i}-x_{2i})^2+(y_{1i}-y_{2i})^2} \qquad [1]$$

With: ***p*** the number of points which constitute each vector, each vector has the same size p.
x_i, y_i: the coordinates of the i^{th} point of the vector to be recognized ***V_1*** .
x_i, y_i: the coordinates of the i^{th} point of a vector of the basis ***V_2*** .

The system decides that the person to identify corresponds to the person in the database which has the maximum of similar points, i.e. the minimum distance d. So the role of identification is to confirm that it is such and such a person or say that this person does not belong to the database. This ID is parameterized by a variable threshold (see Fig.2)

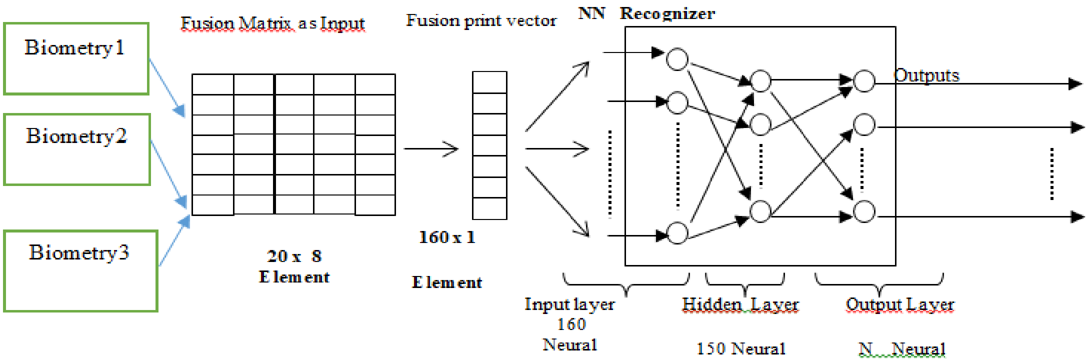

Figure.3.b – Architecture of the system with neural network approach

Validation, Implementation and Testing

We note that the volume of calculations involved and the volume of data to be processed is very high, and that it is therefore quite possible that WorkStations may be required for such implementations. For this we proceed by their differents steps :

- Selection of suitable platforms (Matlab, Java, ...)
- Use of powerful machines or workstations (Sun workstation)
- Possible use of BEAT evaluation platform,
- Possible use of specialized software such as Munitia Cyl, SFinGe, ...
- Realization of biometric systems on real data.

In this phase we will test our system, i.e. identify a person from their three biometric images or modalities (face, iris, and fingerprint). This phase proceeds as follows:

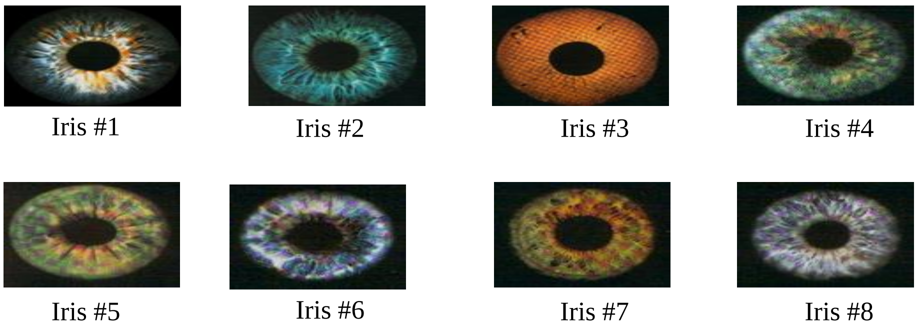

Figure.4.a.Samples from iris database.


Figure 4.b. Samples from face database.


Figure 4.c. Samples from fingerprint database.

For this, we built test groups. For the MIT database, we added different synthetic noises (tq: the noises of Salt & papper, of Speckle, of Gauss, and Poisson) to the original images (whose threshold varies between 0.03 and 0.04). For the CMU database, we have several versions of images from the face (several emotional states), we built 4 test groups with only the photo of the face which changes (emotion), the others that of the iris and that of the fingerprint remain the same.

Discussion

Neural networks are used for classification and prediction, and are systems for making input/output associations. They have the ability to learn, which gives them the appearance of universal approximators. This has been seen and observed in this approach. Compared to the first Euclidean distance-based approach, the neural approach gave encouraging results too. Admittedly, the RN recognized all the people in the training groups (which is to be expected), but in the test it gave erroneous results despite the low threshold of added noise. This system which is based on notions of smart distance to make the Matching, allowed us to obtain very good results / encouraging results and favorable. For the MIT base, he recognized all people despite the threshold of the added noise, and the same goes for the base CMU, and as a perspective, we will test our approach with the following multi-biometric databases TIMIT, XM2VTS, BANCA, NIST, FVC.

Conclusion

In this paper, first results have been obtained on a multimodal biometric fusion system that uses face, iris and fingerprint features for automatic verification. A feature-level fusion scheme was proposed, in which two different approaches were developed, the first using Euclidean distance for comparison. According to the experiments carried out, the performance of the multimodal system is superior to the individual performance of the single-mode systems. In conclusion, it should be mentioned that it is possible to combine more than three modalities with an integration of modules such as the one we have used: the only problem is to access the measurements given by each of the single-mode modules, i.e. sensors and modules, in order to extract the characteristics present. All these recommendations are avenues for future work.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

Acknowledgements or Notes

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