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Multi-modal Biometrics Identification using Multi-arrays Representation Modal and Pre-Mapping Technique

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***Abstract*– Keeping confidential information is becoming more difficult in an increasingly digital world. Neither classic authentication model nor uni-modal biometric system provides enough security to ensure that data is protected out of the unauthorized individuals. For this multi-modal biometric system has become the best suited solution when high level of accuracy and security is required as it requires two biometric credentials for positive identification instead of one in uni-modal biometric system. Traditional multi-modal biometric system uses multi-database fields to get the different biometric credentials and therefore multi matching mechanisms. In this paper we improve the technique to speed up the use of multimodal biometric system by representing the biometric codes and apply fusion over the represented codes so single matching process will be used.**

***Index Terms*– Biometric, Multi-modal Biometric System, Fusion*, Multi-arrays Model, Pre-mapping and Post-mapping**

I. INTRODUCTION

ONE of the main challenges facing system security today is confirming the true identity of a person. Biometrics has been around for many years while several studies have emerged to present and highlight the advantages of multi-modal biometric systems over traditional authentication modal and uni-modal biometric systems [1]. Used a frequency based approach for features incorporation in fingerprint and iris multi-modal biometric identification systems.

They have innovated multi-modal biometric identification system depend on iris and fingerprint traits. The study results in a homogeneous biometric vector that integrates iris and fingerprint data.

Many other studies were applied to implement different ways to extract the final decision from the multi-modal biometric system. The studies were varied, some studies worked separately on each biometric and considered multi-matching process and combined the decision of each biometric to get the final decision (post-mapping) [2]–[9]. Others worked on the fusion of biometrics features (Pre-mapping) [10], [11].

The traditional multi-modal biometric systems are using different sensors for different biometrics and fusion the results [12]. Any biometric system goes through four important phases: the sensor phase which captures the trait in the form of raw biometric data; the feature extraction phase which processes the input data and extract a feature set of the trait; the matching phase which applies a comparison over the extracted feature set and the stored templates to generate matching scores; the decision phase which uses the resulted matching scores to either determine an identity or validate a claimed identity. As shown in Fig. 1.

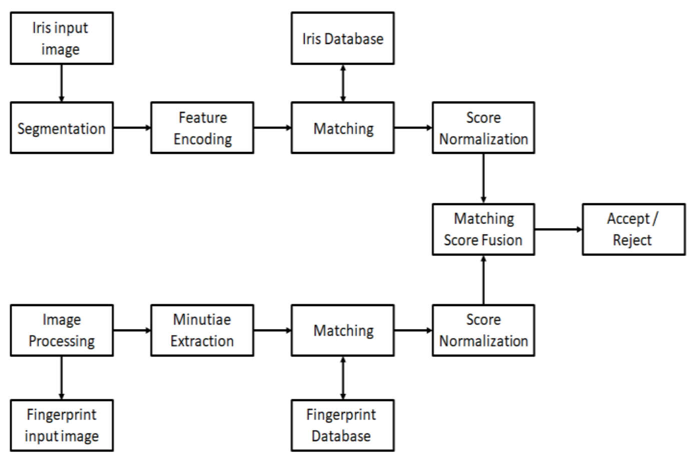

Fig. 1: Schematic diagram of multi-modal biometric system

II. PROPOSED METHOD

The fusion strategies can be classified into two main categories: pre-mapping fusion (before the matching phase) and post-mapping fusion (after the matching phase). The traditional pre-mapping fusion used to deal with the sensor level fusion and/or feature level fusion which led to many implementation problems and thus the post-mapping fusion is the trustworthy way in the multi-modal biometric system.

In this paper, we develop new pre-mapping fusion strategy that deal neither with the sensor level nor the feature level but with new invented level (Feature representation level) as shown in Fig. 2. The proposed representation process to the biometric features enhance and speed-up the matching process.

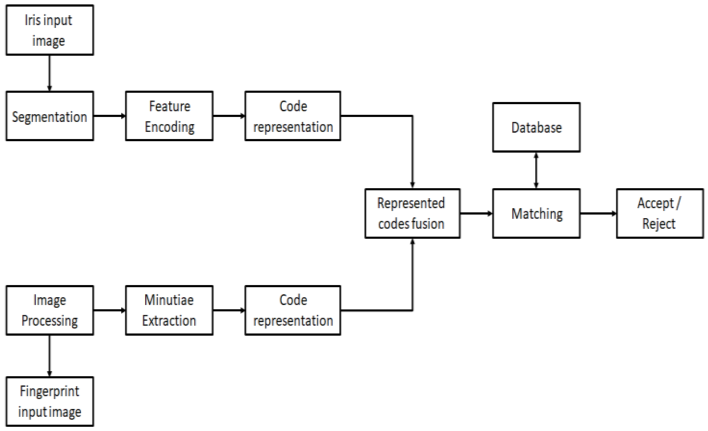

Fig. 2: Schematic diagram of proposed pre-mapping fusion strategy for multi-modal biometric system

A) Proposed biometric feature representation

The main idea of our multi-arrays modal is that to represent the biometric codes inside the stored dataset, this operation will represent each consecutive pair in the biometric code by one bit.

To do so we will use three one dimensional arrays the first one will be structure array that contains integers and strings while the other two arrays will be integer arrays. Fig. 3 represents the multi-arrays modal biometric codes representation flow chart.

Fig. 4 shows how to represent the biometric code using the multi-arrays modal, it applies the multi-arrays modal over 12-bit codes.

The proposed multi-arrays modal will be applied over all the biometrics that are used in the multi-modal biometric system and then fusion will be applied on the biometrics arrays (represented features).

B) Matching process over the represented and fused biometrics

The multi-arrays modal provides two stages of matching operations, the initial matching stage and the main matching stage. These stages play primary role in speeding up the matching process. The matching will be applied over the final fused arrays for multi-biometrics.

Initial matching stage:

In this stage we can benefit from the number of pointer that goes from array 1 to array 2, (P), that we have got after applying the biometric representation operation using multi-arrays modal, by taking the difference of the pointers between the two codes which will allow us to calculate the Initial Hamming Distance.

1- If the Initial Hamming Distance exceeds the allowed threshold (HD ≥ .32) [13], then we can decide that the two codes are not for the same person, without the need to compare each bit in the biometric codes.

2- If the Initial Hamming Distance does not exceed the allowed threshold (HD ≤ .32), then we have to move to the second stage (Main comparison operation).

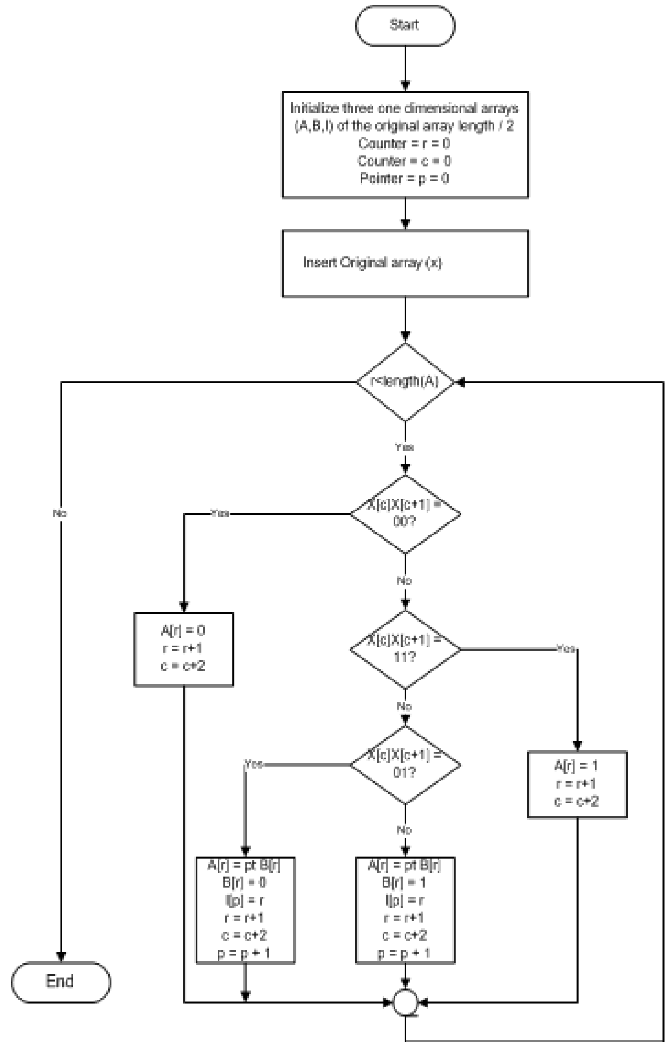

Fig. 3: multi-arrays modal biometric codes representation flow chart

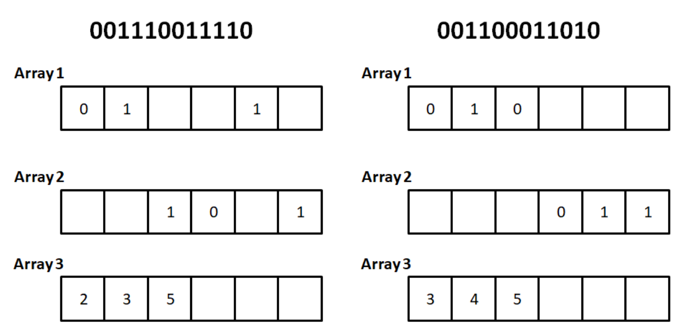

Fig. 4: apply the multi-arrays modal over 12-bit codes

How to calculate the difference between the pointers?

To calculate the difference of the pointers between the needed biometric codes we use the third array, which contains the pointers location (index) in the first array. To drop this on figure 3 where third array of the first code = {2,3,5} and third array of the second code = {3,4,5}, here the difference = 2.

From this we can allocate the formula to calculate the difference as:

$$Difference = (I1 \cup I2) - (I1 \cap I2) \qquad (1)$$

Main matching stage:

In this stage, we benefit from the Initial HD to calculate what we called a Comparison factor (C factor), in order not to visit all the bits of the codes as in the traditional method.

How to calculate the C factor:

We can define the C factor as the maximum number of differences that allowed to be found between the two biometric codes such that when calculate the HD not exceeds the allowed threshold .32. So we can calculate the C factor as in eq. (2).

$$C = N * .32 \qquad (2)$$

Where C represents the Comparison factor and N is the total number of biometric code bits.

How to apply multi-arrays main matching:

In this stage, we will take the sealing of (length of first array) / 2 and then refer to third array to find how many difference are there in the second half of first array, and then apply a bit by bit comparison on the first half of the first array. When the bit by bit comparison applied over the first half we will check:

1- If the number of differences in the first half plus the specified differences in the second half exceeds the C factor then the biometric codes are not for the same person.
2- If the number of differences in the first half plus the specified differences in the second half does not exceed the C factor, then we will repeat the same operation but this time we will take half the remained part.
3- We have to repeat steps 1 and 2 until either the two codes are for different persons or the specified differences plus all the remained bits does not exceeds the C factor, that time we can decide that the given codes relate to the same person.

Note that when applying the bit by bit matching it is not necessary to access the second array such that when the first array for the first pattern contains a 0 or 1 and the corresponding place in array for the second pattern contains a pointer then we will record a difference without access the second array of the second pattern as discussed in Table 1.

Fig. 5 represents the biometric codes matching criteria using our multi-arrays model flow chart.

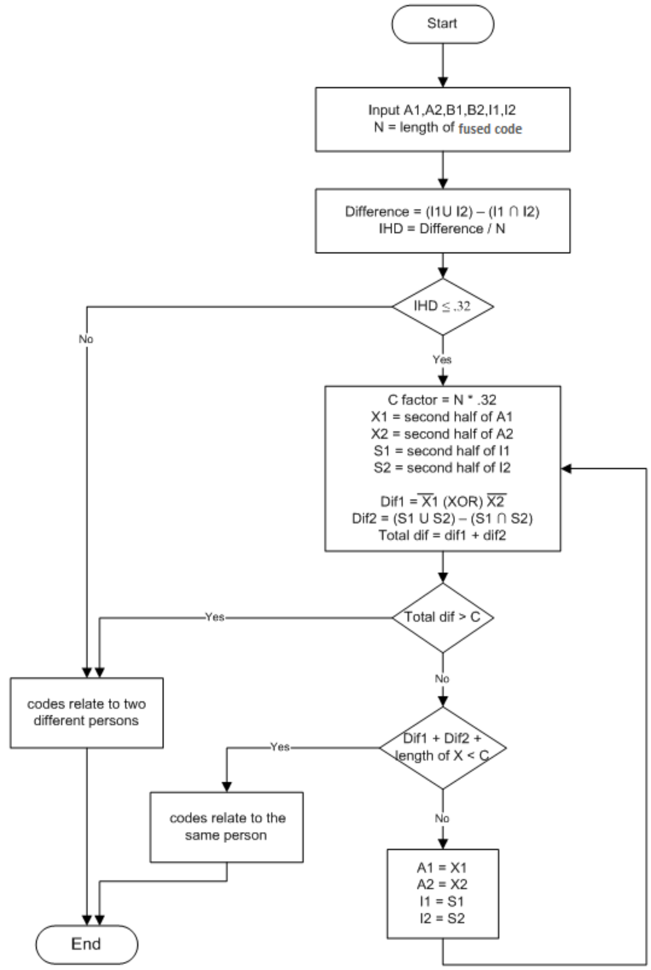

Fig. 5: biometric codes matching criteria using multi-arrays model flow chart

III. MATHEMATICAL ANALYSIS

In mathematical analysis we calculated the complexity of the new multi-arrays modal aside with the standard biometric code recognition modal, the modals complexities will provide a clear indicator to the enhancements that were made over the standard modal via the multi-arrays modal.

The standard biometric code recognition modal complexity:

The basic operation for the standard biometric code recognition modal is the bit by bit comparison operation at the biometric code level; this operation has the complexity of M, where M represents the length of the biometric code and the complexity of fusion of the matching scores. So for the multi-modal biometric system that use two biometric codes the complexity will be as shown in 3.

$$C(S) = 2M + 2N + 1 \qquad (3)$$

Where C(S) is the complexity of the standard biometric code recognition, M is the number of bits in the first code and N is the number of bits in the second code.

The proposed multi-arrays modal complexity:

The multi-arrays modal complexity is equal to the summation of the biometric code representation step complexity and the matching operation complexity which is determined by the summation of the initial matching step and the main matching step. Table 1 illustrates the multi-arrays modal basic operations and their complexities.

Table 1: The proposed multi-arrays modal basic operations and their complexities

Basic Operation	Operation Complexity
The biometric code representation step	*L*, where *L* represents the length of the fused biometric code.
The initial matching operation	*1*, this is a linear operation.
The main matching operation	(*L* - *C*), where *L* is the total number of fused biometric code bits and *C* is the C factor.

The complexity of the proposed multi-arrays modal will vary between the summation of the biometric code representation complexity, the initial matching operation complexity and the summation of the biometric code representation complexity, the initial matching operation complexity and the main matching operation complexity. As in eq. (4) and eq. (5).

between:

$$C(MA) = L + 1 \quad (4)$$

and

$$C(MA) = L + (L - C) + 1 \quad (5)$$

Where C(MA) is the multi-arrays modal complexity and L is the biometric code representation complexity, 1 refers to the initial matching operation complexity and (L-C) represents the complexity of the main matching operation.

If we apply substitute of L by (M+N) then the final equation for the worst case will be as in 6:

$$C(MA) = 2M + 2N - C + 1 \quad (6)$$

Then worst case of multi-arrays biometric modal can be presented in terms of the standard multi-modal biometric system as in eq. (7).

$$C(MA) = C(S) - C \quad (7)$$

Where C(MA) is the multi-arrays modal complexity, C(S) is the complexity of the standard biometric code recognition and C is the C factor.

IV. CONCLUSIONS

In this paper, we proposed an efficient alternative to the standard human multi-modal biometric system, the multi-arrays modal, which represents the human biometric binary code and then use this representation efficiently to apply the pattern matching.

Using the proposed multi-arrays modal enhanced the exhaustive human multi-modal biometric system so that the bit by bit comparison operation during the matching operation will not be applied over all the human biometric code bits and also this operation will be applied once.

The efficiency of the suggested solution is measured by applying a detailed mathematical analysis for both the standard and the alternative modal.

We find that the best ever achieved improvement resulted when all the biometric code bits lying in the first array and a match occurs after applying the main matching operation only for the first half, at this case the complexity will be 1/4 from the complexity of the standard multi-modal biometric system.

While the worst case achieved when the all the fused biometric code bits lying in the second array and we reach to L – C to determine the codes symmetry.

In both cases the complexity is better than the standard as the worst case complexity is the complexity of the standard minus the C factor.

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