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BIOM 693 Critique # 1

Critique: Fingerprint Identification Using Graph Matching	
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1. Introduction and Objective

This paper describes a novel method for performing the major processing blocks of a fingerprint identification system. In particular, it outlines the encoding and matching blocks based on the use of fingerprint ridge patterns from digital images. Besides using ridge patterns (as opposed to minutiae information) the major contribution the paper offers is an attempt to map the identifying fingerprint information onto a scheme outside the scope of the conventional x-y plane. The authors claim that a scheme that is based on a graph mapping will be less sensitive to noises associated with typical fingerprint images including both affine transformations and non-linear deformations. Specifically, they claim the algorithm is comparably adept at dealing with translations, rotations, compression, expansion, and general spurious noise. In an attempt to justify said claims, they use a small sample of fingerprints from the Royal Canadian Mounted Police. The paper suggests the possibility of practical application in the fields of police criminal identification and verification as well usage in building secure applications.

2. The Encoding Scheme

As mentioned in the introduction, the overall goal of the encoding scheme is to map the fingerprint information into the form of a graph which has apparent differences compared to a conventional x-y mapping. The encoding scheme attempts to convert ridge information (dark portions of the image) into a graph in which ridges are represented by graph nodes and ridge adjacencies are represented by graph edges. This version of the algorithm takes in a grey-scale image of 128 X 128 pixels. To make ridge extraction easier, the algorithm incorporates the use of standard binarizing and ridge thinning techniques. The goal of application of these techniques is to reduce ridges to single pixel widths. After this process, ridges themselves are identified and uniquely numbered using a simple single neighbor algorithm. Each ridge is also given two endpoints (end 1, end 2) and two sides (side 1, side 2) such that the oriented in one of two possible ways. After these identifying characteristics are established three major pieces of information are extracted. One, the length of each ridge in pixels is determined using an extension of the pixel neighbor technique. [It is said that due to high variability of this feature, it is only used as an approximation in the matching block; however, I argue that it seems to play a greater role than claimed]. Two, all neighbors of each ridge are determined using an iterating perpendicular emanation technique. The neighbor characteristic is defined by the authors to be non-reflexive in nature in that a given ridge R1 may be a neighbor to ridge

R2 yet is does not necessitate that R2 is a neighbor to R1. [Due to this non-reflexive property, it seems that every ridge must be traversed in an exhaustive fashion, pixel by pixel. Intuitively this should have a significant effect on computation time]. A similar emanation technique is then used to calculate neighbor overlap for each ridge. [The authors seem to indicate that this process occurs after all neighbors are determined; once again, a process exhaustive in nature which intuitively will have a negative impact on computation time]. Level information represents the third and final major piece of information that is extracted about the ridges. These levels are created by the various ridges / ridge bifurcations of the print and are determined using a somewhat involved recursive technique that makes use of the side information of each ridge. [It appears that the outlining of such levels seems to offer only cardinal information; how many levels a given print has compared to another. At the same time, the authors acknowledge that this can be highly variable from different versions of each print. The authors also point out that even if cardinality is variable, relativity of levels is maintained. I fail to see the importance of this characteristic much less how it is used in either graph creation or matching despite the authors claim that it is important]. Finally, a graph is created is constructed with nodes representing ridges and edges representing connections to side and end neighbors. The graph is said to include encoded information on ridge length, the orientation of the ridge, and the overlap of the ridge. Finally the authors address how the encoding algorithm allows for the reparation of broken ridges and how it discounts the special minutiae of ridge crossovers. [It seems odd that the authors indicate that repairing broken ridges is a desirable feature immediately after pointing out that typically this information is considered unreliable by experts. If broken ridges are unreliable sources of information, how could a fix of said ridges result in information any more reliable?]

[It is clear there is a difference in the process of matching two fingerprints in the x-y plane versus the process of matching two graphs. However, it seems that in order to support the authors claims, the encoding process would also have to be removed from the x-y plane. I would argue that this does not occur. All information regarding ridge length, overlap, and neighbors is extracted using the pixel array from the image which is simply the x-y plane. Therefore, although the final mapping is in graph format, that mapping is fundamentally based on information from the x-y plane which is said to be susceptible to the noise in which the graph is supposed to be insensitive to].

3. Matching

After the encoding process has mapped the fingerprint information to graph format, the matching algorithm aims to determine how similar two graphs are to one another. The paper breaks this process down into three subsections; partitioning, refinement, scoring. In partitioning, the algorithm goes through the space of possible node similarities of the two graphs and attempts to eliminate pairs that do not appear to be indicative of a match. It uses two rules to filter out pairs. One based on ridge length and another based on the number of neighbors it has. [Although, the authors claim that ridge length is used as an approximation, 50% of the partitioning rules are based on it, perhaps more than an approximation]. Next, the refinement portion further narrows the scope of possible matching by performing an exhaustive filter based on the neighbor mapping of each node on one graph to the neighbor mapping of each node on another. Finally, the scoring portion involves taking the remaining scope of possible node matches and attempts to find the best fit using a tree generation process. Each possible mapping is expanded as a scored tree based on the number and type of minutiae that have been matched. Since the possibility exists for a given node to generate multiple mappings, the tree with the highest score will be selected with the overall result being a sum of all the maximum trees. [The most notable deletion from this paper is what determines the score of a given tree. For instance, it is known exactly how the portioning and refinement portions operate; they incorporate ridge length and neighbor information. What features does the tree scoring portion use? One can only assume that it must include level numbers, otherwise, it appears they are used nowhere in the matching process.]

4. Experimental Results

All testing of the algorithm was done via 5 (5 users) images of size 1536 X 1536. Many overlapping 512 X 512 windows were extracted from the original 5 images to form a testing database. Furthermore, after binarization and thinning, the 512 X 512 windows were reduced to 128 X 128 pixels in which encoding and matching was performed. These numbers resulted in 289 total trials (214 “imposter” and 75 “genuine”). [The authors indicates that the algorithm correctly indicates matching areas whenever they exist. Although no biometric systems work perfectly, the claim of the authors that the algorithm matches areas correctly appears accurate upon granting a rather rigid assumption. It does provide higher matching scores when comparing the same exact window against itself. Beyond that, the algorithm discriminates between imposter and genuine users weakly at best (see figure 1)].

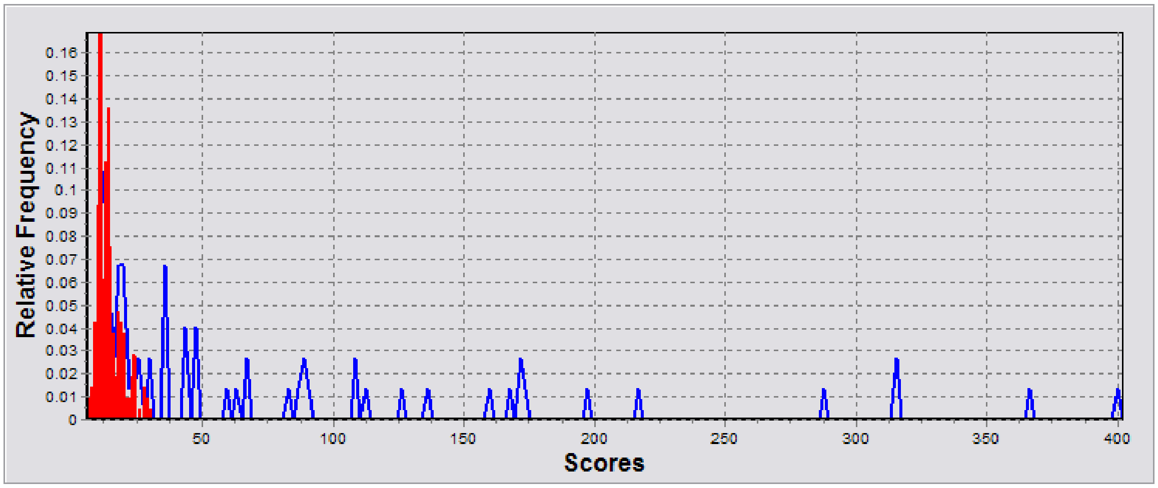

Figure 1- Genuine vs. Imposter Score Distrubution

[Further analysis shows that the score space generates a rather weak ROC curve (see figure 2) with an EER of almost 30% at a threshold of 75].

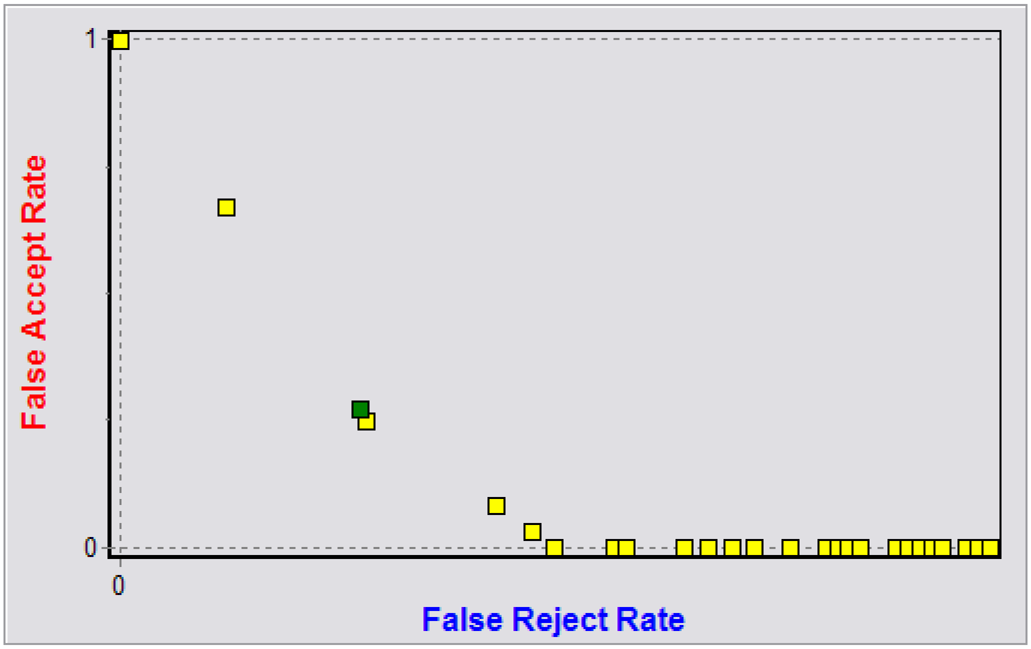

Figure 2- ROC Curve, Threshold 75, EER-0.271331

[Despite the seemingly poor results, the overall methodology for the process seems suspect. There is no real control for the experiment when testing the images. With “genuine” users being represented by partitioned windows from the original images, they actually represent partial, translated fingerprints. Furthermore, unless compared identical images, the process compares partial, translated fingerprints to partial translated fingerprints. Therefore, the authors seem to be presenting results of images with extreme noise yet do not compare them to ones without noise (control). Furthermore, the testing process does not include the presence of any image rotation due to the window technique. Therefore, any such claims on the performance of the algorithm relative to this noise have not been substantiated].

5. Conclusion and Overall Analysis

[The paper presents a novel technique for matching digitized fingerprints. The algorithm provides both encoding and matching blocks which are based on mapping fingerprint information into the form of graphs. It is proposed that the graph format is less sensitive to noise than conventional x-y plane algorithms. I disagree that the techniques outlined in the paper succeed in fully mapping the information onto something different from the x-y plane due to the inherent implications of the encoding process.

Despite the claims of the author, the paper seems to provide somewhat poor results. Furthermore, even if the results provided were more promising the overall method of testing would not support the claims of the authors regarding a insensitivity to rotational noise.

I imagine the testing methodology and unsupported claims probably stem from the preliminary nature of the paper and immature state of the field at the time it was published. All this having been said, it seems the overall idea of the paper could have promising results if applied properly. However, clearly these procedures would have to be tested on databases of much more substantial size].