Chapter 6

Intra-Modal Score level Fusion for Off-line Signature Recognition

6.1 Introduction

The feature set derived from single technique may produce higher error rates. In such cases, two results from different techniques are fused to improve the system performance. In the proposed Intra-Modal Score level Fusion for Off-line Signature Recognition (ISFOSR), the signature image is resized, skeletonized, and exact signature area is obtained by preprocessing. The geometric features of signature are obtained by counting the number of black pixels and locating geometric centers. The geometric centers of test signature are compared with database signature using correlation to generate correlation matching score. The angular features are generated for test and database signature and compared using distance to generate distance matching score. The correlation matching score and distance matching score of the signature are fused using efficiency parameters to verify the authenticity of an individual effectively.

6.2 ISFOSR model

In this section, the block diagram of ISFOSR system shown in Figure 6.1 is discussed in detail. The signature images are resized and skeletonized. The exact signature area is considered. Two types
of features are extracted in two stages. The geometric centers of signature are obtained by vertical and horizontal splitting of signature to get sixty features. The one hundred and sixty eight angular features are extracted by splitting the signature in two phases. The geometric centers of signature are compared using correlation and the angular features are compared using distance formula for authentication.

6.2.1 Signature database

The GPDS300 is an off-line handwritten signature database, which contains 24 genuine signatures and 30 forgeries of 300 individuals [119, 120] and available in PNG format. The local database consisting of ten genuine and ten forgery signatures per person from eleven persons that is totally 220 signature images is also used as input.

6.2.2 Preprocessing

The signature image is preprocessed to enhance image quality. The preprocessing includes filtering, resizing, skeletonization by morphological operations and considering the exact signature area. These preprocessing steps are discussed in detail in the previous chapter.
6.2.3 Random Forgery Detection

The Random Forgery is detected before the feature extraction. The number of rows \( r_m \) and columns \( c_m \) of each signature in the database are computed using the Equations 6.5 and 6.6 respectively.

\[
\begin{align*}
  r_m &= a_{1m} - a_{2m} \quad \text{(6.5)} \\
  c_m &= a_{3m} - a_{4m} \quad \text{(6.6)}
\end{align*}
\]
where \( m \) – number of signature samples in the database, say \( N \)

\[ a_{1m} \] - row with first black pixel from the top of signature

\[ a_{2m} \] - row with first black pixel from the bottom of signature

\[ a_{3m} \] - column with first black pixel from the left of signature

\[ a_{4m} \] - column with first black pixel from the right of signature

The average number of rows \( r_{avg} \) and columns \( c_{avg} \) per person’s signature are computed using the Equations 6.7 and 6.8 respectively.

\[
r_{avg} = \frac{\sum_{m=1}^{N} r_m}{N} \hspace{1cm} \text{----------------- (6.7)}
\]

\[
c_{avg} = \frac{\sum_{m=1}^{N} c_m}{N} \hspace{1cm} \text{----------------- (6.8)}
\]

The number of rows \( r_T \) and columns \( c_T \) of test signature are computed and compared with \( r_{avg} \) and \( c_{avg} \) respectively. The absolute value of the difference between \( r_{avg} \) and \( r_T \) and the absolute value of the difference between \( c_{avg} \) and \( c_T \) are computed using the Equations 6.9 and 6.10.

\[
r_D = \left| r_T - r_{avg} \right| \hspace{1cm} \text{----------------- (6.9)}
\]

\[
c_D = \left| c_T - c_{avg} \right| \hspace{1cm} \text{----------------- (6.10)}
\]
The computed absolute differences $r_D$ and $c_D$ are compared with predefined threshold values and if $r_D$ and $c_D$ are greater than threshold, then the test signature is random forgery signature.

6.2.4 Feature Extraction

The two set of features are extracted form the preprocessed signature images. They are geometric centers and angular features. The extraction of these features is explained as follows.

(i) Geometric Centers: The two sets of geometric features are extracted by vertical and horizontal splitting of preprocessed signature. The geometric centers represent the stroke distribution of signature pixels. The sixty features are computed using geometric centers. The thirty geometric centers are obtained from each of the vertical and horizontal splitting. The total number of geometric centers is sixty. The detailed discussions on generating geometric centers from vertical and horizontal splits are given in section 5.2.3.

(ii) Angular features: The angular features are extracted from the preprocessed signature in two phases. In first phase, the preprocessed signature is segmented into one hundred and twenty eight blocks by vertical and horizontal splitting. The one hundred and twenty eight angles are computed from these blocks. In the second phase the preprocessed signature is segmented into ten blocks from each of the four corners and the total number of blocks from all corners is forty. The forty angular features are computed from all forty blocks. The detailed procedure for generating one
hundred and sixty eight angular features is discussed in detail in section 5.3.4.

6.2.5 Matching

(i) Correlation matching of geometric centers of signature:

The geometric centers of test signature are compared with geometric centers of genuine signatures in the database using correlation to compute FRR and FAR.

(ii) Distance matching of angular features:

The angular features of test signature are compared with angular features of genuine signatures in the database using absolute difference values of angular features to compute FRR and FAR.

6.2.6 Fusion

The computed FRR values of geometric centers and angular features are fused using efficiency parameters such as $a$ and $b$ to obtain better FRR values and it is given by the Equation 6.11.

$$FRR_{fusion} = a^2 FRR_1 + b^2 FRR_2 \quad \text{----------------} \quad (6.11)$$

Where $FRR_1$ – FRR of geometric center features

$FRR_2$ – FRR of angular features.

The FAR values computed from geometric centers and angular features are fused using efficiency parameters to obtain better FAR values given by the Equation 6.12.

$$FAR_{fusion} = a^2 FAR_1 + b^2 FAR_2 \quad \text{----------------} \quad (6.12)$$

Where $FAR_1$ – FAR of geometric center features
\( FAR_2 \) – FAR of angular features,

The \( EER \) values computed from geometric centers and angular features are fused using efficiency parameters to obtain better \( EER \) values given by the Equation 6.13.

\[
EER_{fusion} = a^2 EER_1 + b^2 EER_2 \quad \text{----------------- (6.13)}
\]

Where \( EER_1 \) – EER of geometric center features

\( EER_2 \) – EER of angular features,

\( a \) and \( b \) – Efficiency parameters and the relationship between \( a \) and \( b \) is given by the Equation 6.14.

\[
a + b = 1 \quad \text{----------------- (6.14)}
\]

6.3 Proposed ISFOSR Algorithm

Consider a signature image of a subject whose identity has to be verified. The objectives are to:

(i) Extract the features by splitting operation

(ii) Verify the authenticity of the test signature against random and skilled forgery by correlation of center of signature and angular feature

(iii) Obtain low values of FAR and FRR

The ISFOSR algorithm in which the authenticity of the test signature image is verified is given in Table 6.1. The geometric center features and angular features are extracted from preprocessed signature. The efficiency of the algorithm is improved by fusing error rates from geometric centers and angular features.
Table 6.1: ISFOSR Algorithm

- Input: Signature Database and Test signatures
- Output: Match/ Mismatch of test signature

1. Preprocess the signature image and detect random forgery
2. The geometric centre features are obtained by vertical and horizontal splitting
3. The geometric centre features of test signature are compared with geometric centre features of signature in database using correlation to compute \( FRR \), \( FAR \) and \( EER \)
4. The angular features of signatures are extracted using segmentation
5. The angular features of test signature are compared with angular features of signatures in the database using distance matching to compute \( FRR \), \( FAR \) and \( EER \)
6. The values of \( FRR \) computed from geometric centre features and angular features are fused using the equation
   \[
   FRR_{fusion} = a^2 FRR_1 + b^2 FRR_2
   \]
7. The values of \( FAR \) computed from geometric centre features and angular features are fused using the equation
   \[
   FAR_{fusion} = a^2 FAR_1 + b^2 FAR_2
   \]
8. The values of \( EER \) computed from geometric centre features and angular features are fused using the equation
   \[
   EER_{fusion} = a^2 EER_1 + b^2 EER_2
   \]


### 6.4 Performance Analysis

For the performance analysis, the local signature database and GPDS are considered. The MATLAB version 7.8 is used for implementation of the proposed algorithm. The values EER of geometric center method, angular feature method and proposed fusion method for local database are tabulated in Table 6.2. It is observed that the proposed fusion method has comparatively less error rates.

<table>
<thead>
<tr>
<th>Techniques</th>
<th>EER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geometric center Feature</td>
<td>8.0</td>
</tr>
<tr>
<td>Angular Feature</td>
<td>7.2</td>
</tr>
<tr>
<td>Proposed Fusion method</td>
<td>4.283</td>
</tr>
</tbody>
</table>

The values of EER of geometric center method, angular feature method and proposed fusion method for GPDS database are tabulated in Table 6.3. It is observed that the proposed fusion method has comparatively less error rates.

<table>
<thead>
<tr>
<th>Techniques</th>
<th>EER</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSRCG</td>
<td>27.99</td>
</tr>
<tr>
<td>OSRAF</td>
<td>26.34</td>
</tr>
<tr>
<td>Proposed Fusion method</td>
<td>21.28</td>
</tr>
</tbody>
</table>
The comparison of EER values of the proposed ISFOSR model with existing methods are given in Table 6.4. The EER value of the proposed model is better compared to existing methods presented by Hairong Lv al., [122], Rekik et al., [123] and Suhail and Manal [124]. The performance of the proposed algorithm is improved because of fusion of matching scores of different techniques.

Table 6.4: Comparison of EER values of the proposed method with existing methods for GPDS database

<table>
<thead>
<tr>
<th>Method</th>
<th>Preprocessing</th>
<th>Feature extraction</th>
<th>% EER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hairong Lv et al., [122]</td>
<td>Noise reduction, binarization, thinning</td>
<td>Moment features, Direction, gray and stroke width distribution</td>
<td>27.9</td>
</tr>
<tr>
<td>Rekik et al., [123]</td>
<td>Binarization, histogram, median filter</td>
<td>Signature segmentation into blocks</td>
<td>32.83</td>
</tr>
<tr>
<td>Suhail and Manal [124]</td>
<td>Resize, Binarization, segmentation, thinning</td>
<td>Eccentricity, skewness, orientation</td>
<td>36</td>
</tr>
<tr>
<td><strong>Proposed ISFOSR method</strong></td>
<td><strong>Resize, skeletonization, exact signature area</strong></td>
<td><strong>Fusion of Geometric centers and Angular features</strong></td>
<td><strong>21.28</strong></td>
</tr>
</tbody>
</table>

6.5 Summary

The proposed ISFOSR algorithm, which is based on fusion of correlation matching score of geometric centers of signature and distance matching score of angular features is more efficient, accurate and robust. Two sets of features are extracted in two stages. In the first stage, geometric centers of signature and in the second
stage angular features are extracted. The geometric centers are compared using correlation and angular features are compared using distance metric against pre-defined threshold. The algorithm is made efficient by two stage feature extraction and eliminating the random forgeries after the preprocessing. The error rates are further improved by matching score level fusion of the two feature sets.