Chapter 5

FEATURE EXTRACTION AND CLASSIFICATION

5.1 INTRODUCTION

The most important aspect of any biometric based authentication system to achieve high performance is the selection of appropriate feature set which should be reasonably invariant with different degradations. This chapter describes the (1) process of feature extraction used for gender discrimination and authentication, (2) feature selection and (3) classifiers used in this research work.

5.2 FEATURE EXTRACTION

Three different types of features namely binary moment features, anatomical features and spatiotemporal features extracted for implementation of our system are described in this section.

5.2.1 Extraction of Binary Moment Features

Moment functions have a broad spectrum of applications in image analysis. Moments are features of the object, which do not have a direct understandable geometrical meaning. For a 2D continuous function $f(x,y)$ the moment (sometimes called "raw moment") of order $(p + q)$ is defined as in eq.(5.1) [127].

$$M_{pq} = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} x^p y^q f(x,y) dx dy \quad (5.1)$$
Adapting this to grayscale image with pixel intensities \( f(x,y) \), raw image moments \( M_{pq} \) are calculated by eq.(5.2).

\[
M_{pq} = \sum_{x} \sum_{y} x^p y^q f(x,y)
\]  
(5.2)

For binary image since \( f(x,y) = 1 \), the raw image moments are calculated by eq.(5.3):

\[
M_{pq} = \sum_{x} \sum_{y} x^p y^q
\]  
(5.3)

The moments computed with respect to the object centroid are called central moments and are defined as eq. (5.4)

\[
\mu_{pq} = \iint_{-\infty}^{\infty} (x - \bar{x})^p (y - \bar{y})^q f(x,y) dx dy
\]  
(5.4)

where \( \bar{x} \) and \( \bar{y} \) is defined as eq.(5.5) and eq.(5.6).

\[
\bar{x} = \frac{M_{10}}{M_{00}}
\]  
(5.5)

\[
\bar{y} = \frac{M_{01}}{M_{00}}
\]  
(5.6)

If \( f(x, y) \) is a digital image, then eq. (5.4) becomes eq. (5.7).

\[
\mu_{pq} = \sum_{x} \sum_{y} (x - \bar{x})^p (y - \bar{y})^q f(x,y)
\]  
(5.7)

The central moments of order up to 2 expressed in terms of raw moments are given by eq. (5.8) to eq. (5.13).

\[
\mu_{00} = M_{00}
\]  
(5.8)

\[
\mu_{01} = 0
\]  
(5.9)
\[ \mu_{10} = 0 \]  
\[ \mu_{11} = M_{11} - \bar{x}M_{01} = M_{11} - \bar{y}M_{00} \]  
\[ \mu_{20} = M_{20} - \bar{x}M_{00} \]  
\[ \mu_{02} = M_{02} - \bar{y}M_{00} \]  

Above moments computed from a digital image generally represent global characteristics of the image shape and provide a lot of information about different types of geometrical features of the image such as area, centroid (xmean and ymean), orientation, length of major and minor axis, aspect ratio and eccentricity. These geometrical features can be calculated using 0th, 1st and 2nd order moments as given from eq. (5.14) to eq. (5.19)

\[ \text{Area} = \mu_{00} \]  
\[ \text{xmean} = \frac{M_{10}}{M_{00}} \]  
\[ \text{ymean} = \frac{M_{01}}{M_{00}} \]  

\[ \text{Aspect ratio} = \text{major axis length/ minor axis length} \]  
\[ \text{Eccentricity} = \frac{(\mu_{11} - \mu_{20})^2 - 4\mu_{11}^2}{(\mu_{20} + \mu_{02})^2} \]  
\[ \text{Angle} = 0.5 \text{ atan } \left( \frac{2\mu_{11}}{\mu_2 - \mu_0} \right) \]  

where \( \mu'_{20}, \mu'_0, \) and \( \mu'_1 \) are defined as in eq.(5.20), eq. (5.21) and eq. (5.22).

\[ \frac{\mu'_{20}}{\mu_0} = \frac{M_{20}}{M_{00}} - \bar{x}^2 \]  

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\[ \mu'_{02} = \frac{\mu_{02}}{\mu_{00}} = \frac{M_{02}}{M_{00}} - \bar{y}^2 \]  
(5.21)

\[ \mu'_{11} = \frac{\mu_{11}}{\mu_{00}} = \frac{M_{11}}{M_{00}} - \bar{x}\bar{y} \]  
(5.22)

5.2.2 Extraction of Anatomical Features

Different positions of the human body according to anatomical studies are given in Figure 5.1. Based on this study, vertical positions of ankle 0.039H, knee 0.285H, hip 0.530H, chest 0.720H, shoulder 0.818H and head 0.870H are estimated as shown in Figure 5.2. Body height (H) is obtained by measuring the height of the bounding rectangle which encloses the silhouette contour, from the bottom of the bounding rectangle. Pixel-wise height, width and all possible ratios of body parts are then calculated based on this division.

Figure 5.1 Anatomical Division of Human Body [128]
Bounding rectangle’s mean height ‘H’ is obtained by averaging the difference between upper and bottom points on y axis at each time instant t given by eq.(5.23):

\[ H = \frac{\sum_{t}^{n} Y_{up}(t) - Y_{bp}(t)}{N} \]  \hspace{2cm} (5.23)

where \( Y_{up} \) is the upper point on y axis, \( Y_{bp} \) is the bottom point on y axis and \( N \) is the number of frames in the gait cycle.

5.2.3 Extraction of Spatiotemporal Features

Bounding rectangle’s height and width over a gait cycle is used for obtaining spatial features. Height ‘H’ is obtained by averaging the difference between upper and bottom points on y axis at each time instant t using the eq. (5.23). Width ‘W’ is obtained by averaging the difference between right and left points on x axis at each time instant is given by eq. (5.24):

\[ W = \frac{\sum_{i=1}^{N} [X_{rp}(t) - X_{lp}(t)]}{N} \] \hspace{2cm} (5.24)

where \( X_{rp} \) is the right point on x axis, \( X_{lp} \) is the left point on x axis and \( N \) is the number of frames in the gait cycle. These features are used for obtaining Diagonal angle
‘A’ and Aspect ratio ‘AR’ as given in eq. (5.25) and eq. (5.26). Figure 5.3 shows the sample pictorial representation of the computed height, width, and diagonal angle.

\[
A = \frac{\sum_{i=1}^{N} \left[ \frac{tan^{-1} \left( \frac{H(t)}{W(t)} \right)}{N} \right]}{N} \tag{5.25}
\]

\[
AR = \frac{\sum_{i=1}^{N} \left[ \frac{H(t)}{W(t)} \right]}{N} \tag{5.26}
\]

Figure 5.3 Height and Width of the Silhouette and Diagonal Angle

Step length, Stride length, Cadence and Velocity are considered as temporal components. Step length and stride lengths are computed by finding the number of frames in a step and stride which is shown in Figure 5.4. Cadence is number of steps per minute and it is calculated by finding the number of frames per second because all the videos in the database are 2-4 seconds video. Velocity is calculated by the equation eq. (5.27).

\[
Velocity = stride\ length \times 0.5\ Cadence \tag{5.27}
\]
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