CHAPTER 3 HUMAN POSTURE ANALYSIS

This chapter describes the silhouette-based posture analysis that is applied to estimate single person postures. In our system, human postures are the feature used in human action recognition, which will be described in the next chapter. Because of this, the posture of a single person has to be estimated, after the single person is detected. In section 3.1, which types of postures are used in action recognition is described. What are the features used to represent a human posture is specified in section 3.2. Section 3.3 explains how to estimate a single person posture using the features.

3.1 Types of Postures

Human are in various postures while they are performing actions. In other words, a human action is considered as a sequence of postures. Each posture has different appearances, varying with the angle of view.

We collected samples of indoor human actions from a variety of viewing angles and analyzed the actions to detect the changes in posture. We observed that human postures can be grouped into seven main postures roughly. The seven main postures are listed as follows.

1. Standing
2. Stooping
3. Sitting with crooked legs
4. Squatting
5. Keeling
6. Sitting with stretched legs
7. Lying down/prone

Fig. 3.1 shows an example of the seven main postures. Each main posture can further be

(a) (b) (c) (d)

(e) (f) (g)

Fig. 3.1 An example of the seven main postures. (a) Standing. (b) Stooping. (c) Sitting with crooked legs. (d) Squatting. (e) Keeling. (f) Sitting with stretched legs. (g) Lying down/prone.

divided into eight view-based appearances according to the difference between its appearances that vary with the angle of view. The eight view-based appearances range from 0° to 315° with 45° increment. The eight view-based appearances of a sitting with stretched legs posture is shown in Fig. 3.2. So there are 56 appearances (postures) used for human action recognition in our system, including the seven main postures and the eight view-based appearances for each main posture.

3.2 Posture Description

In our system, the posture of a single person is represented by the centroid, the major axis, and the normalized silhouette of the single person silhouette, which are shape features of

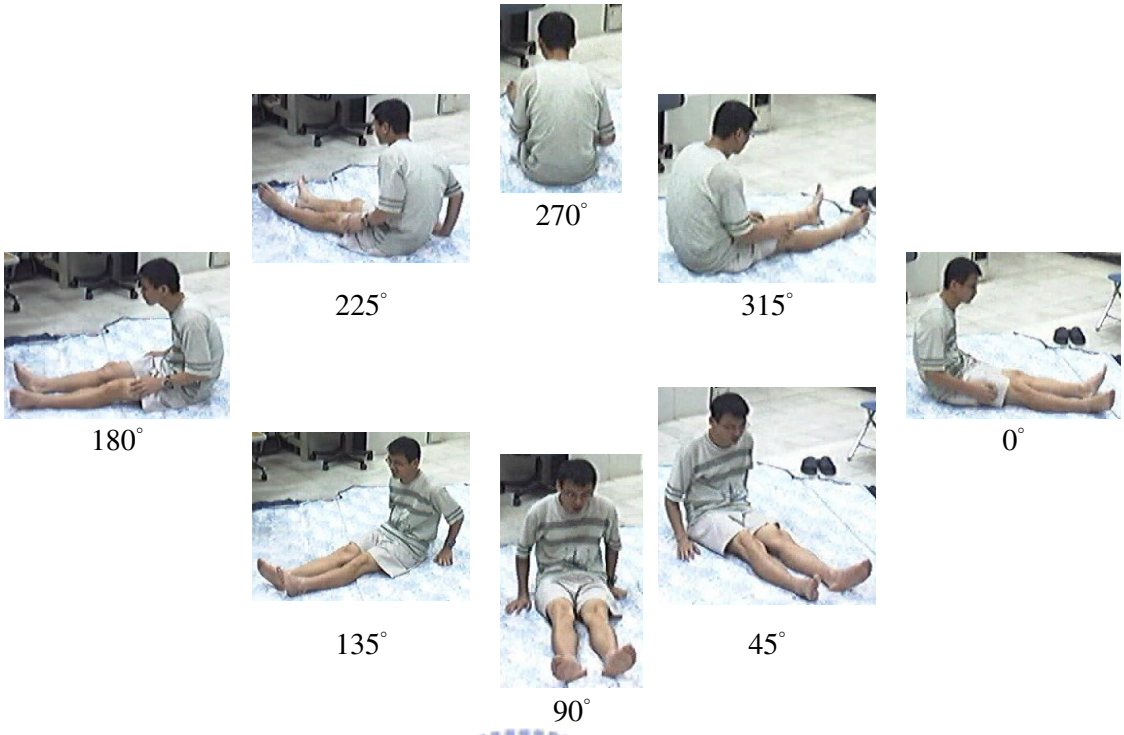


Fig. 3.2 The eight view-based appearances of a sitting with stretched legs posture.

the silhouette. Fig. 3.3 shows the shape features of a single person silhouette.

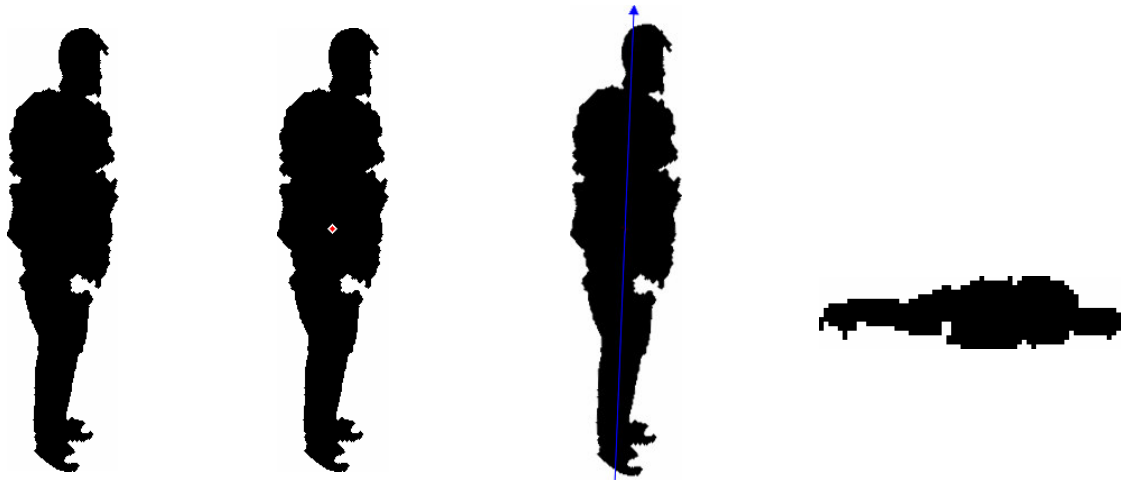
Centroid: The centroid of a single person silhouette, denoted by (m_x, m_y), can be calculated as

$$(m_x, m_y) = \frac{1}{N} \sum_{(x,y) \in \text{silhouette region}} (x, y)$$

where N is the number of pixels of the silhouette region. The centroid is also used to represent the position of the single person in the image.

Major axis: The major axis of a single person silhouette is determined by applying a principal component analysis (PCA) to the silhouette pixels. The major axis is used to represent the orientation of the single person posture. The direction of the major axis is given by an eigenvector v associated with the largest eigenvalue of the covariance matrix of the silhouette pixels.

Normalized silhouette: The normalized silhouette of a single person silhouette, denoted



(a) (b) (c) (d)

Fig. 3.3 The shape features of a single person silhouette. (a) A single person silhouette. (b) Its centroid. (c) Its major axis. (d) Its normalized silhouette.

by T, can be calculated using the procedure as follows.

1) Relocate all pixels of the single person silhouette with a new coordinate system, where the x-axis is the major axis of the silhouette, the y-axis is the perpendicular axis of the major axis, and the origin is the centroid of the silhouette.
2) Construct the bounding rectangle of the result of 1), and resize the bounding rectangle to fit the length of the longest side to 64 pixels.
3) Normalize the result of 1) by rescaling the result into the resized bounding rectangle.

The procedure for calculating the normalized silhouette of a single person silhouette also can be illustrated with Fig. 3.4. The location of each pixel of T is represented relative to the centroid of T, and the centroid is assumed $(0,0)$. The value of each pixel of T is assumed 1. That is,

$$T(x,y)=\begin{cases}1, & if \quad (x,y)\in T\\ 0, & otherwise\end{cases}.$$

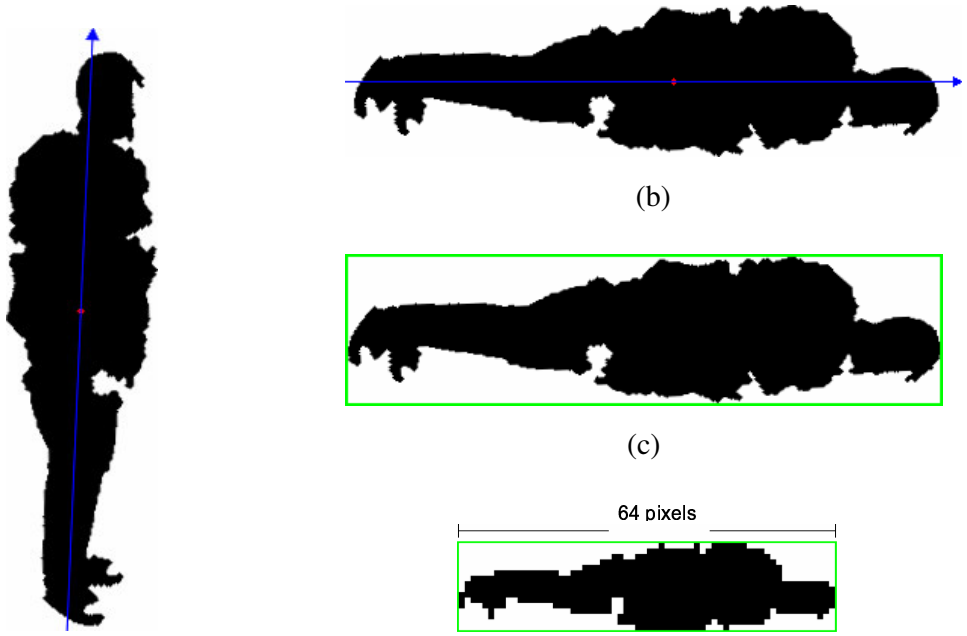


Fig. 3.4 The procedure for calculating the normalized silhouette of a single person silhouette. (a) A single person silhouette with its centroid and major axis. (b) 1) Pixel relocation. (c) 2) Bounding rectangle construction. (d) 3) Silhouette normalization.

3.3 Posture Estimation

In our system, the posture of each single person is classified into one of the seven main postures. For posture estimation, the posture of a single person is classified into one of the 56 appearances (postures), described in section 3.1, and then is considered as the main posture that the appearance (posture) belongs to.

Each of the 56 appearances (postures) is represented by the average major axis, and the average normalized silhouette of a sample of its silhouettes. In our system, the average major axis and the average normalized silhouette for each appearance (posture) were calculated using 1,500 silhouettes of five different humans.

Average major axis: Let $\{\vec{u}_1, \vec{u}_2, \cdots, \vec{u}_N\}$ be the unit vectors representing the directions of the major axes for a sample of one appearance silhouettes. The direction of the average

major axis for the sample of the appearance silhouettes, denoted by $\vec{m}$, can be calculated as

$$\vec{m} = \frac{1}{N}\sum_{i=1}^{N}\vec{u}_i .$$

Average normalized silhouette: Let $\{T_1, T_2, \cdots, T_N\}$ be the normalized silhouettes of a sample of one appearance silhouettes. The average normalized silhouette of the sample of the appearance silhouettes, denoted by P, can be calculated as

$$P(x, y) = \frac{1}{N}\sum_{i=1}^{N} T_i(x, y), \text{ for all } (x, y) \in \bigcup_{i=1}^{N} T_i .$$

Fig. 3.5 shows some of the normalized silhouettes of the appearances (postures) used in posture estimation.

To estimate the posture of a single person, the normalized silhouette of the single person is compared with the average normalized silhouettes of the 56 appearances using the sum of absolute differences. Let S_i be the similarity between the single person posture and the *i*th appearance, P_i the average normalized silhouette of the *i*th appearance, and T the normalized silhouette of the single person. S_i can be calculated as

$$S_i = \sum_{(x,y)\in T \cup \{(a,b) \mid (a,b)\in P_i \wedge P_i(a,b)=1\}} |T(x, y) - P_i(x, y)| .$$

The most similar appearance is determined by using the lowest score. The posture of the single person is considered as the main posture that the most similar appearance belongs to.

Posture estimation only using the average normalized silhouettes is not absolutely correct. For example, the posture of a single person that is a standing posture with the viewing angle 180° could be classified as a lying down/prone posture with the viewing angle 180°, since the average normalized silhouettes of standing 180° and lying down/prone 180° are very similar (see Fig. 3.5). The average major axis is useful to avoid this error. While the posture of a single person is classified as one of two similar average normalized silhouettes, the major axis of the single person has to be compared with the average major axes of these two appearances. Then, the single person posture is classified as the appearance whose average major axis is most similar to the major axis of the single person in direction.

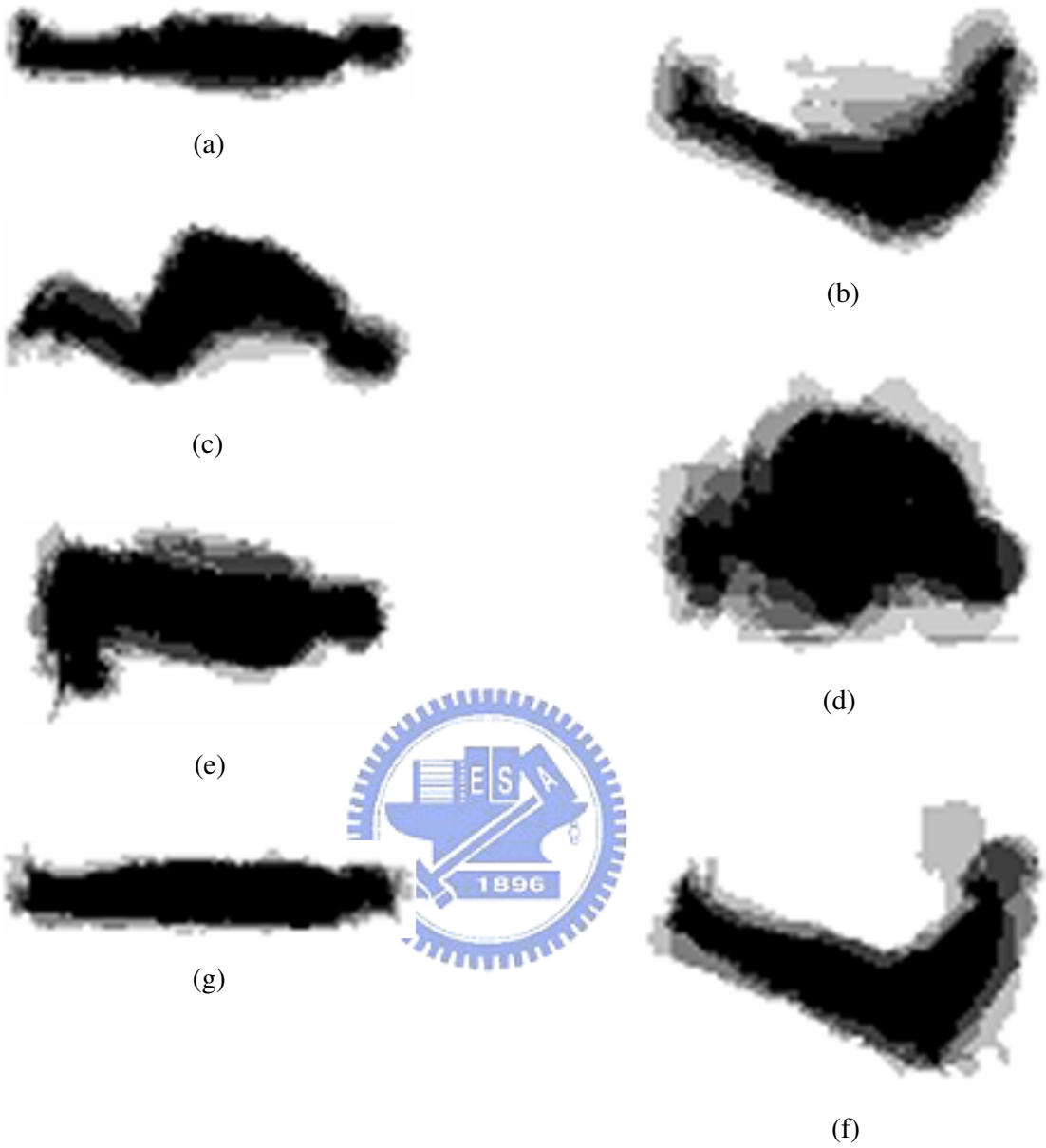


Fig. 3.5 Some of the normalized silhouettes of the appearances (postures) used in posture estimation. (a) Standing 180°. (b) Stooping 180°. (c) Sitting with crooked legs 0°. (d) Squatting 45°. (e) Kneeling 135°. (f) Sitting with stretched legs 180°. (g) Lying down/prone 180°.