行政院國家科學委員會專題研究計畫 成果報告

具方位適應性之人類步伐辨識系統
研究成果報告(精簡版)

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計 畫 編 號 ：NSC 97-2221-E-216-042-
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計畫主持人：連振昌
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報 告 附 件 ：出席國際會議研究心得報告及發表論文

處 理 方 式 ：本計畫可公開查詢

中 華 民 國 98年10月26日

行政院國家科學委員會補助專題研究計畫 ■ 成 果 報 告
□期中進度報告

（計畫名稱）

具方位適應性之人類步伐辨識系統

計畫類別：■ 個別型計畫　　□ 整合型計畫
計畫編號：NSC 97-2221-E-216 -042 -
執行期間： 97 年 8 月 1 日至 98 年 7 月 31 日

計畫主持人：連振昌
共同主持人：石昭玲
計畫參與人員：田志強、林佩蓉、蔡雅婷

成果報告類型(依經費核定清單規定繳交)：■精簡報告　□完整報告

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■出席國際學術會議心得報告及發表之論文各一份
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□涉及專利或其他智慧財產權，■一年□二年後可公開查詢

執行單位：中華大學資訊工程學系
中　華　民　國　98　年　10　月　22　日

一、中文摘要

人類步伐辨識方法大致上分為二大類：以影像為基礎的步伐辨識方法與以模型為基礎之步伐辨識方法。以影像為基礎的步伐辨識方法較易受到不精準的前景偵測之影響。而以模型為基礎之步伐辨識方法較能避免受到不精準的前景偵測之影響，從而擷取人類步伐的動作特徵。但是以模型為基礎之步伐辨識方法中步伐模型比對之計算量通常很大。為了克服此問題，於本計畫我們提出一個動態步伐模型的比對方法，同時也提出全新之以模型為基礎之步伐投影特徵來改善人類步伐辨識的效能及準確性。此外視角轉換技術也應用到本計畫以解決人行走時不同視角時，能將其步伐影像轉換至正視角提升人類步伐辨識的正確度。最後於本計畫，數項人類步伐特徵也會做比較從而驗證各項步伐特徵的特性。

關鍵字：步伐辨識、動態步伐模型、步伐投影特徵

二、英文摘要

The methods of human gait recognition can be categorized into image-based and model-based methods. Image-based methods are easily affected by the inaccurate foreground detection. Model-based methods can extract the gait features (joint angles) robustly and avoid the noise interference problem but the gait model fitting process is time consuming. To overcome these shortcomings, a dynamic gait model fitting algorithm is proposed to fit the gait model to the silhouette image sequence of a walking people efficiently. Then a new model-based projection feature and model-based gait features are generated to improve the recognition accuracy. Furthermore, view transformation for the gait images is applied to recognized human identities for arbitrarily view angles. Finally, the accuracy of human gait recognition using various kinds of gait features is analyzed.

Keywords: human gait recognition, dynamic gait model fitting, model-based gait features

三、報告內容

此研究成果已刊登於 IEEE Second International Conference on Innovative Computing, Information and Control (ICICIC 2007)

Cheng-Chang Lien, Chih-Chiang Tien, and Jia-Ming Shih, “Human gait recognition for arbitrary view angles,” IEEE Second International Conference on Innovative Computing, Information and Control (ICICIC 2007), Sep. 5-7, 2007, Kumamoto, Japan. (EI)

Human Gait Recognition for Arbitrary View Angles

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Abstract

The methods of human gait recognition can be categorized into image-based and model-based methods. Image-based methods are easily affected by the inaccurate foreground detection. Model-based methods can extract the gait features (joint angles) robustly and avoid the noise interference problem. However, the gait model fitting process is time consuming. To overcome these shortcomings, a dynamic gait model fitting algorithm is proposed to fit the gait model to the silhouette image sequence of a walking people efficiently. Then a new model-based projection feature and model-based gait features are generated to improve the recognition accuracy. Furthermore, view transformation for the gait images is applied to recognized human identities for arbitrarily view angles. Finally, the accuracy of human gait recognition using various kinds of gait features is analyzed.

1. Introduction

Psychological studies [1] show that it is feasible to identify human identity by using gait signatures. Hence, human gait recognition is frequently applied to a variety of applications, e.g., human identity recognition, access control, video surveillance, etc. The methods of human gait recognition can be categorized into image-based and model-based methods.

In the image-based gait recognition approaches [2-5], image features used to recognize the human identity are extracted from the silhouette image. Because the image features are extracted by using background subtraction, edge mapping or optical flow detection, they are sensitive to noise, background cluttering, illumination change and the distance of object to camera. The vague silhouette image will introduce an imprecise feature extraction and make the human gait recognition inaccurate.

On the contrary, model-based approaches can extract the gait features robustly. In [9] the movements of the thighs are modeled as an interlinked pendulum to extract the angular variation. The gait feature extraction using the model-based method can avoid the noise interference problem [6]. When the silhouette image of a walking people is vague, the model-based methods [6, 9] still can extract trajectory of moving human and gait features (joint angles). However, gait model fitting process is time consuming.

To overcome the abovementioned shortcomings for both the image-based and model-based methods, an efficient dynamic gait model fitting algorithm is proposed to fit the gait model to the silhouette images. Then model-based image projection features and model-based gait features are generated to improve the recognition accuracy. Furthermore, many conventional gait recognition approaches limit that the walking direction has to be parallel to the image plane. Here, the view angle transformation [7, 8] is applied to solve the problem when people walk with arbitrary view angles.

2. View Angle Transformation for Image-Based Gait Feature Extraction

Because high recognition rate is achieved when human gait is observed from the canonical view, the image transformation from the side view to the canonical view [7] is applied to extract a reliable image-based gait features.

2.1 Image Transformation from Side View to Canonical View

The method of view transformation is developed from the concept of perspective projection shown in Fig. 1. Assume that a person of height h walks along the line AC and subtends an angle θ with the projection plane. The line AB is parallel to the plane XY. An image point p (human head in image plane) with image coordinate [x, y] is obtained by projecting the 3-D point P (human head in world coordinate) with world coordinate [X, Y, Z] to image plane. In Fig. 1, the point O is the position of camera, Z_0 denotes the distance of the person to the camera, α denotes the angle formed by projecting the trajectory of human walking on the image plane, and f denotes the focal length. Based on the perspective projection, the following equality can be derived.

$$Z = Tan(\theta)X + Z_0, Y = h\,. \qquad (1)$$

By projecting the 3-D point to image plane, the coordinates of 2-D image point can be derived as:

$$x = f\frac{X}{Z_0 + Tan(\theta)X},\ y = f\frac{Y}{Z_0 + Tan(\theta)X}. \qquad (2)$$

Let K=-h/Z_0, the equality for angles θ and α can be written as:

$$Tan(\theta) = \frac{1}{K}Tan(\alpha)\,. \qquad (3)$$

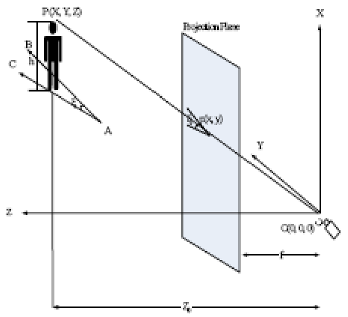

Figure 1. Image geometry of perspective projection.

The coordinate transformation from the side view to the canonical view can be written as:

$$x_0 = f\frac{x_\theta \cos(\theta) + f\sin(\theta)}{-x_\theta \sin(\theta) + f\cos(\theta)},\ y_0 = f\frac{y_\theta}{-x_\theta Sin(\theta) + fCos(\theta)} \qquad (4)$$

2.2 Image Projection Feature

Image projection feature [7] is frequently applied to recognize the human gaits, which is formed by projecting the gait image along row or column directions. Image projection features shown in Fig. 2-(a) and 2-(c) are constructed by projecting silhouette images along the row and column directions. Projection feature images shown in Fig. 2-(b) and 2-(d) are formed by accumulating a sequence of image projection features.

3. Dynamic Model Fitting for Gait Feature Extraction

3.1 Dynamic Human Gait Model

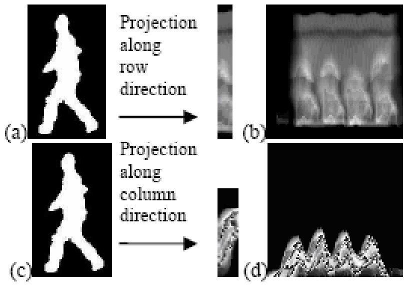

Figure 2. Projection feature images are shown in (b) and (d) are constructed by accumulating a sequence of image projection features in (a) and (c) respectively.

Here, the human model used to fit the human gaits is constructed with five rectangles. By the careful observation, the length ratio for head, body, and foot is about 1: 2: 3. The human model is shown in Fig. 3. In the human model, joint angles θ_1, θ_2, θ_3, and θ_4 are used to describe the joint angles on the legs. The complete human model is established with the angle feature vector Θ = {θ_1, θ_2, θ_3, θ_4} and the links L= {l_1, l_2, l_3, l_4}. Then, the complete human model is represented as H = {Θ, L}.

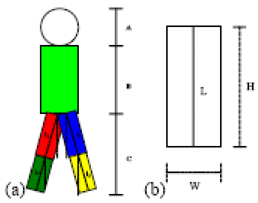

Figure 3. (a) Human model is constructed with five rectangles. Symbols A, B, and C denote the lengths of head, body, and foot. The joint angles on the legs are denoted as θ_1, θ_2, θ_3, and θ_4. The lings' lengths are denoted as l_1, l_2, l_3, and l_4. (b) The length ration of height to width for each rectangle is set as 3 : 1.

In most model-based methods [6, 9], the fitting process is complex and time consuming. To improve the efficiency, a dynamic gait model that simulates cycle movements of human walking is proposed.

3.2 Dynamic Human Gait Model Fitting

The dynamic gait fitting algorithm is described as:

1. Extract the skeleton of the silhouette image of tracked subject shown in Fig. 4-(a).
2. Adjust the length of gait model according to the tracked subject and set the size of each component according to the length ratio (1: 2: 3) for head, body,

and leg.

3. Locate each rectangle (component of gait model) at the corresponding position on the skeleton shown in Fig. 4-(b).
4. Based on the tracking of leg movements, the moving state (lifting or standing) of each leg is determined by estimating whether the joint angles' variation is increasing or decreasing. The left picture in Fig. 4-(c) shows that the left leg is standing and the joint angles of gait model of left leg are decreasing; while the right picture in Fig. 4-(c) shows that the right leg is lifting and the joint angles of gait model of right leg are increasing during following silhouette frames.
5. Each part of gait model is located to the silhouette image by minimizing the fitting error :

$$E(M,R) = \arg\max_{\theta} Num(M \cap R), \qquad (5)$$

where M is gait model, R is the silhouette image, θ is the angle parameters of rectangles (components of gait model), and $Num(M \cap R)$ denotes the pixel number that gait model overlaps with silhouette image. The result of dynamic gait model fitting is shown in Fig. 4-(d).

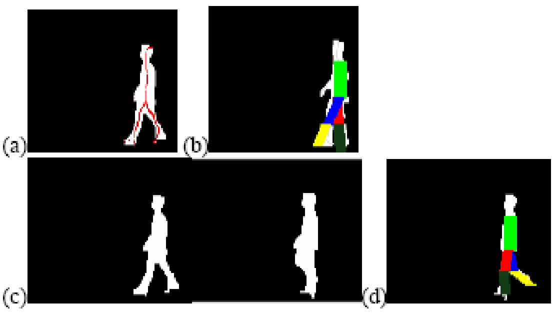

Figure 4. (a) Skeleton of the silhouette image. (b) Initial model construction. (c) Walking movements. (d) An example of dynamic gait model fitting.

4. Human Gait Recognition

4.1 Model-based Gait Features

Based on the dynamic human gait model fitting process, two gait features including model-based projection features and model-based angle features are generated. Image-based projection features mentioned in section 2 are easily affected by the inaccurate foreground detection and then model-based projection feature is proposed to improve this problem. Model-based projection feature is constructed by projecting the fitted human gait model along row direction. Model-based angle feature is constructed by extracting the joint angles on the fitted human model during the human walking movements. Based on the model fitting process the effect of inaccurate foreground detection can be reduced significantly. Given a video sequence of human walking, joint angle variation curves for the leg movements shown in Fig. 5 are extracted by using the dynamic gait fitting algorithm.

4.2 Human Gait Recognition Using Projection Features

To recognize the human identity with image-based and model-based projection features the method of correlation matching is adopted.

$$\gamma = \frac{\sum_t \sum_s [f(s,t) - \bar{f}][w(s,t) - \bar{w}]}{\{\sum_s \sum_t [f(s,t) - \bar{f}]^2 [w(s,t) - \bar{w}]^2\}^{1/2}}, \qquad (6)$$

where s, t are the coordinate indexes, f and w denote two images, and $\bar{f}$ and $\bar{w}$ are the average value of f and w respectively.

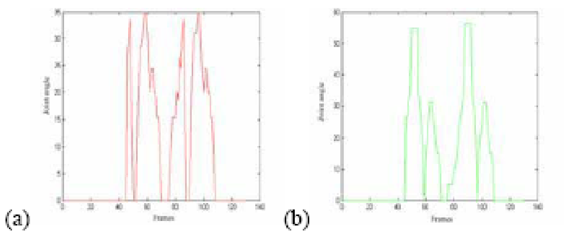

Figure 5. The curves of joint angle's variation on (a) right thigh and (b) right shank.

4.3 Human Gait Recognition Using Model-Based Angle Feature

Given a video sequence of human walking, joint angle variation curves for the leg movements are extracted by using the dynamic gait fitting algorithm and shown in Fig. 4. Then, Fast Fourier transform (FFT) is applied to generate the model-based angle feature which is scale and translation invariant. Once the model-based angle feature is acquired, LDA (Linear Discriminant Analysis) is used to recognize the human identity.

5. Experimental Results

The human gait recognition for arbitrary view angles are analyzed with three kinds of gait features: image-based projection feature, model-based projection feature, and model-based angle feature. The video database is constructed by recording the video sequences of ten peoples' walking movements with four view angles: $\theta = 0°, 15°, 30°, 45°$. Six video clips are recorded for each view angle and each person. In total, there are 240 video clips in the database and each sequence consists of one gait cycle.

5.1 Human gait recognition using the model-based projection feature

Model-based projection feature is proposed to improve imprecise image-based projection features. The correlation matching is also used to recognize the human identity and the recognition accuracy is illustrated in Fig. 6. The recognition accuracy is improved about 4% to the image-based method. The model-based projection method outperforms the image-based projection method because model-based approaches may reduce the influence of noise interference and illumination change. However, the detail information of leg movements is lost during the projection process such that the recognition accuracy is not satisfied.

5.2 Human gait recognition using the model-based joint angle feature

Human gait recognition using the model-based joint angle feature is developed by extracting the FFT coefficient vector for the joint angle variation of leg movements shown in Fig. 5 and then applying the LDA method to recognize human gaits. The accuracy analysis of human gait recognition is shown in Fig. 6. It is obviously that the model-based method is superior to the other methods because the detail information of leg movements is extracted to recognize the human gaits. Finally, Fig. 6 shows the accuracy analyses of human gait recognition systems using the various kinds of gait features.

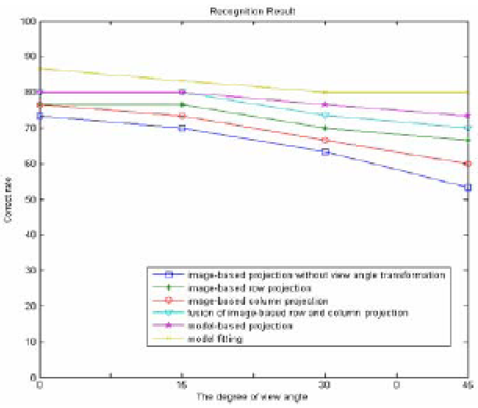

Fig. 6. The accuracy analysis for the human gait recognition using the various kinds of gait features.

6. Conclusion

An efficient dynamic gait model fitting algorithm is proposed to fit the gait model to the silhouette image sequence of a walking people and then a new model-based projection feature and model-based gait features are generated. View transformation is applied to transform the gait images from side view to canonical view and then the human identity can be identified for arbitrarily view angles. Experimental results show that the model-based projection feature can improve the recognition accuracy of the conventional image-based projection features.

7. Reference

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可供推廣之研發成果資料表

■ 可申請專利　　□ 可技術移轉　　日期：＿年＿月＿日

國科會補助計畫	計畫名稱：**具方位適應性之人類步伐辨識系統** 計畫主持人：　連振昌 計畫編號：NSC 97-2221-E-216 -042 - 學門領域：資訊學門(二)
技術/創作名稱	**具方位適應性之人類步伐辨識系統**
發明人/創作人	連振昌 田志強
技術說明	中文：人類步伐辨識方法大致上分為二大類：以影像為基礎的步伐辨識方法與以模型為基礎之步伐辨識方法。以影像為基礎的步伐辨識方法較易受到不精準的前景偵測之影響。而以模型為基礎之步伐辨識方法較能避免受到不精準的前景偵測之影響，從而擷取人類步伐的動作特徵。但是以模型為基礎之步伐辨識方法中步伐模型比對之計算量通常很大。為了克服此問題，於本計畫我們提出一個動態步伐模型的比對方法，同時也提出全新之以模型為基礎之步伐投影特徵來改善人類步伐辨識的效能及準確性。此外視角轉換技術也應用到本計畫以解決人行走時不同視角時，能將其步伐影像轉換至正視角提升人類步伐辨識的正確度。最後於本計畫，數項人類步伐特徵也會做比較從而驗證各項步伐特徵的特性。
	英文：The methods of human gait recognition can be categorized into image-based and model-based methods. Image-based methods are easily affected by the inaccurate foreground detection. Model-based methods can extract the gait features (joint angles) robustly and avoid the noise interference problem but the gait model fitting process is time consuming. To overcome these shortcomings, a dynamic gait model fitting algorithm is proposed to fit the gait model to the silhouette image sequence of a walking people efficiently. Then a new model-based projection feature and model-based gait features are generated to improve the recognition accuracy. Furthermore, view transformation for the gait images is applied to recognized human identities for arbitrarily view angles. Finally, the accuracy of human gait recognition using various kinds of gait features is analyzed.
可利用之產業 及 可開發之產品	安全監控
技術特點	於本計畫我們提出一個動態步伐模型的比對方法，同時也提出全新之以模型為基礎之步伐投影特徵來改善人類步伐辨識的效能及準確性。此外視角轉換技術也應用到本計畫以解決人行走時不同視角時，能將其步伐影像轉換至正視角提升人類步伐辨識的正確度。

推廣及運用的價值	

※　1.每項研發成果請填寫一式二份，一份隨成果報告送繳本會，一份送　貴單位研發成果推廣單位（如技術移轉中心）。

※　**2.本項研發成果若尚未申請專利，請勿揭露可申請專利之主要內容。**

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行政院國家科學委員會補助國內專家學者出席國際學術會議報告

98 年 10 月 22 日

附件三

報告人姓名	連振昌	服務機構及職稱	中華大學資訊工程學系 副教授
時間 會議 地點	Tokyo Japan, May 20-22, 2009	本會核定 補助文號	NSC 97-2221-E-216 -042 -
會議名稱	（中文）IAPR 機器視覺應用國際會議 （英文）IAPR Workshop on Machine Vision Applications.		
發表論文題目	（中文）使用多攝影機換手機制之大型區域監控系統 （英文）Large Area Video Surveillance System with Handoff Scheme among Multiple Cameras		

一、參加會議經過

本人於2009年5月20-22日赴日本東京參加 “IAPR Workshop on Machine Vision Applications 2009” 國際會議，會中發表論文一篇，如下所示：

Cheng-Chang Lien, Yue-Min Jiang, Lih-Guong Jang, “Large Area Video Surveillance System with Handoff Scheme among Multiple Cameras,” *IAPR Workshop on Machine Vision Applications*, Tokyo Japan, May 20-22, 2009, pp. 463-469.

二、與會心得

會議中與各國學者作深切的學術交流，獲益良多。

三、考察參觀活動(無是項活動者省略)

無

四、建議

無

五、攜回資料名稱及內容

MVA 2009 論文集