# Human Gait Description Using a Spatiotemporal Model

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## Abstract / Résumé

In this project, we aim at describing the human gait by using spatiotemporal models. Global trajectory and average walking frequency are the focus points of the project. Extraction of the global walking trajectory is done by evaluating the position with a homography matrix. This matrix allows a correspondence to be established between the real scene and its 2D projection and thus, to compute the trajectory of the contact point during the video sequence. The spatiotemporal model from Adelson and Bergen [1] is used to obtain the "braided pattern" representing the ankles' motion during a walk. Using a morphological approach combined with a median filter, we are able to shrink the "braided patterns" and obtain a 1-pixel width signal. The FFT of this signal allows us to compute the fundamental frequency, namely the average walking cycle period.

Le but de ce projet est de caractériser la démarche humaine à l'aide de modèles spatiotemporels. La trajectoire globale et la fréquence moyenne de marche sont les points ciblés par ce projet. L'extraction de la trajectoire de marche globale est faite en évaluant la position avec une matrice d'homographie. Cette matrice permet d'établir une correspondance entre la vraie scène et sa projection 2D, et de calculer ainsi la trajectoire du point de contact durant la séquence vidéo. L'approche d'Adelson et Bergen [1] est utilisé pour obtenir "le modèle tressé" représentant le déplacement des chevilles pendant la marche. En utilisant une approche morphologique combinée avec un filtre médian, nous pouvons rétrécir "les modèles tressés" et obtenir un signal de 1 pixel de largeur. Une transformée de Fourier de ce signal permet de calculer la fréquence fondamentale, à savoir la période moyenne d'un cycle de marche.

## 1. Introduction

Human gait analysis can provide biometric measures to recognize persons by using their motion pattern. Gait recognition represents an interesting alternative to face recognition, particularly in situations where the subject is located at a certain distance from the camera, where the particular features of his face are not easy to detect. This study presents a simple, yet robust approach for tracking a person, and computing his trajectory as well as the average period of a walking cycle. In order to extract relevant motion features, we propose an approach inspired by the human motion perception, namely the Adelson and Bergen [1] spatiotemporal model. This model has already been applied to the tracking and recognition of walking persons [2]. However, the above-mentioned objectives of our study, as well as our approach for analyzing the "braided patterns" of the spatiotemporal model are different from [2].

## 2. Proposed Approach

The proposed approach for characterizing the human gait is as described in the following diagram:
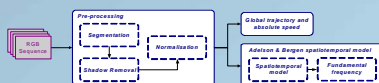


Pre-processing is an important part of the characterization since it rearranges the data into a format which can easily be interpreted. The other two blocks constitute the analysis proper.

## 3. Pre-processing

### 3.1 Segmentation

Segmentation is obtained by background subtraction based on a Gaussian statistical model. The human silhouette is segmented on a frame-by-frame basis, using an identical threshold value on each RBG channel.

$$D(i,j) = |R(i,j) - R_0(i,j)| + |G(i,j) - G_0(i,j)| + |G(i,j) - G_0(i,j)|$$

Two thresholds are used to segment the silhouette. Once $T_{max}$ is reached, 8-connected pixels with a value above $T_{min}$ are included in the segmented region.



### 3.2 Shadow Removal

The resulting segmentation does not remove all undesirable regions, like silhouette shadow. Here, shadow is removed using geometrical analysis of the segmented silhouette. When an important change of orientation in the silhouette contour is detected at the base, the previous section is removed from the blob.



### 3.3 Normalisation

In order to eliminate the depth dependency of the silhouette, a fixed-size bounding box is used for normalisation. A fixed-size box maintains the proportions between the limbs. A bi-cubic interpolation algorithm is used to normalize the boxes.

## 4. Global trajectory and absolute speed

### 4.1 Global Trajectory

The goal of this step is to determine the global trajectory of a walking person. To simplify the calculations, we assume that the person walks on a horizontal plane and that the contact point with the surface is the lowest point of the segmented silhouette.

Prior to obtaining the global trajectory, a few computations must be performed. Firstly, the extraction of the x coordinate of the centroïd allows us to calculate the contact point necessary for the next steps.
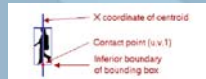


Secondly, five points are selected on the background image and their coordinates are estimated. These points are used to compute the homography.

Eight equations are needed to solve, by singular value decomposition (SVD), the 9 coefficients of the projection matrix.

Finally, the back-projection of the image point into the world reference frame is calculated by multiplying the image points by the inverse projection matrix.

$$\begin{bmatrix} su \\ sv \\ s \end{bmatrix} = \begin{bmatrix} h_1 & h_2 & h_3 \\ h_4 & h_5 & h_6 \\ h_7 & h_8 & h_9 \end{bmatrix} * \begin{bmatrix} x \\ z \\ 1 \end{bmatrix} = \begin{bmatrix} h_1 & h_2 & h_3 \\ h_4 & h_5 & h_6 \\ h_7 & h_8 & h_9 \end{bmatrix} * \begin{bmatrix} x \\ z \\ 1 \end{bmatrix}$$

$$\begin{bmatrix} sx \\ sz \\ s \end{bmatrix} = \begin{bmatrix} h_1 & h_2 & h_3 \\ h_4 & h_5 & h_6 \\ h_7 & h_8 & h_9 \end{bmatrix}^{-1} * \begin{bmatrix} u \\ v \\ 1 \end{bmatrix}$$

### 4.2 Absolute Speed

The average walking speed is computed by the displacements of the contact points between consecutive frames. The x and z components of the speed are thus obtained and the absolute speed is calculated as follows:

$$V_{abs} = \sqrt{V_X^2 + V_Z^2}$$

## 5. Walking cycle period computation

A spatiotemporal model [1] is used for a general description of the motion. Specifically, the slice (x, t) allows to analyse the spatial orientation of a moving object.

The spatiotemporal model is obtained by adding a temporal dimension and stacking the video frames along it. As shown in the figure on the left, a slice (x, t) is obtained for a given y value. A relevant (x,t) slice is obtained from the pre-processed video sequence and is further used for periodicity analysis.
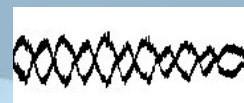
The average walking cycle period is computed using a Fourier Transform on a 1-pixel width signal representing an approximation of the "braided pattern". This pattern is obtained using morphological operators and median filtering.



$$Slice(x,t) = \bigcup_{i=1}^{nframes} F(x,y)^T \Big|_{\substack{x=1:m \\ y=1:j}}$$
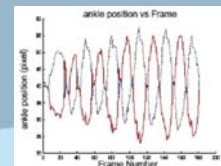


## 6. Results



The database for this study contains video sequences acquired using a monocular camera. Four frames from a typical walking sequence are shown above.

*Global Trajectory and Absolute Speed*
Instant positions are shown by the green curve. One may observe that errors are introduced in computing the positions. The table presents the speed components used to calculate the absolute speed.

| Average Speed | |
|---|---|
| Vx | -1.52 m/s |
| Vy | -0.56 m/s |
| Vabsolute | 1.64 m/s |
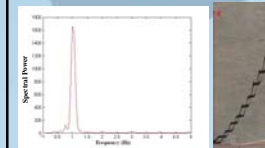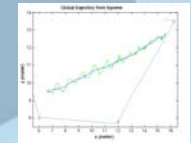




The braided pattern shows the global spatial orientation of the ankles. The extraction of the average walking frequency is successfully accomplished. The frequency obtained corresponds to the expected frequency of 1 Hz.

## 7. Future Work

Ongoing work on this project focuses on optimizing our approach in order to extract real-time trajectory and average frequency and thus, detect events such as sudden direction and/or speed changes in the motion of a walking person.

## 8. Conclusion

An approach was presented to determine the global trajectory of a walking person and extract her average walking cycle period.
Promising results were obtained on a outdoor video sequence of a walking person.

## 9. References

[1] E.H. Adelson, J.R. BERGEN, "Spatiotemporal energy models for the perception of motion", J. Opt. Soc Amer., 2(2), 1985, pp. 284-299.

[2] S.A. Niyogi, E.H. Adelson, Analyzing and recognizing walking figures in XYT. Proc. Of IEEE Conf. On Computer Vision and Pattern Recognition. 1994, pp. 469-474.

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