The CMU Motion of Body (MoBo) Database

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Abstract

In March 2001 we started to collect the CMU Motion of Body (MoBo) database. To date the database contains 25 individuals walking on a treadmill in the CMU 3D room. The subjects perform four different walk patterns: slow walk, fast walk, incline walk and walking with a ball. All subjects are captured using six high resolution color cameras distributed evenly around the treadmill. In this technical report we describe the capture setup, the collection procedure and the organization of the database.

Contents

1 Introduction

In general, locomotion is the process by which an animal moves itself from one geographic position to another [14]. In contrast to the majority of mammals which move on four legs, humans are bipedal. The bipedal locomotion appears to be simpler, yet it requires greater neural control. Humans therefore spend up to the first 15 months of their life acquiring this skill. While the basic pattern of bipedal locomotion are identical between healthy humans, individuals walk differently. The human gait depends on a multitude of factors including physical build and body weight, but also heel hight, clothing and the emotional state of mind of the walker. Nevertheless there is ample anecdotal evidence about people being able to identify acquaintances only based on their manner of walking.

Most studies on human locomotion have been conducted from a biomedical point of view [1]. Recently, the research community has begun to investigate gait as a biometric [4]. While there is a rich body of work describing computer vision systems for modeling and tracking human bodies (see [7] for a review), only a few publications deal with the problem of automatically identifying people from the way they walk [13, 11, 5]. Similarly the knowledge about the human performance on this task is sparse. A number of studies found that humans can recognize gender from gait at greater than chance level [10, 3, 6]. The work by Stevenage et. al. [15] suggests that humans are able to learn the gait characteristics of individuals unknown to them. However, many of these findings are based on a small number of subjects. It is not clear how these results scale to larger databases.

To advance research on human gait as a biometric, we collected the CMU Motion of Body (MoBo) database. To date, we recorded 25 subjects performing four different walking activities on a treadmill. We used six cameras evenly distributed around the treadmill capturing more than 8000 images per subject. The sequences are each 11 seconds long, recorded at full frame rate (30 frames/second). Table 1 gives an overview of the collected data. Figure 1 shows all six views of the database with extracted silhouettes.

Walking Location	Indoor Treadmill
Subjects	25
Views	6
Synchronized	Y
Walk styles	4
Sequence length [sec]	11
Pixel height	500
Frame rate [fps]	30
Size uncompressed [GB]	175
Size compressed [GB]	9.9

Table 1: Overview of the Mobo database.

Figure 1: All six views of the CMU MoBo database with corresponding silhouettes.

An open question remains on biomechanical differences between overground and treadmill walking. So far no conclusive result has been reached with studies finding differences [12] and studies reporting minimal or no differences [2, 8] between the two conditions.

In the reminder of this report we describe the setup of the capture apparatus, the capture procedure and the organization of the database.

2 Capture Setup and Data Collection Procedure

2.1 Camera Setup

Human locomotion is a complex process that involves nearly all the major parts of the body. The visual appearance of the different body parts is view dependent which makes capturing of the complete human body a difficult task. We were able to adapt the CMU 3D Room [9] to capture multiview walk sequences. To keep the data volume per sequence at a manageable level and still be able to compute a full 3D reconstruction, we determined that six cameras evenly distributed around the subject on the treadmill are sufficient. The cameras are high quality (3 CCD, progressive scan) Sony DXC 9000's. The resulting images are 640x480 in size with 24-bit color resolution. As the subjects in our database are spatially more or less stationary on the treadmill, we were able to capture a high resolution image of the person. Furthermore, all the cameras are calibrated and synchronized.

Figure 2 depicts the position of the cameras with respect to the treadmill in the room. Figure 3 shows a panoramic view of the 3D room.

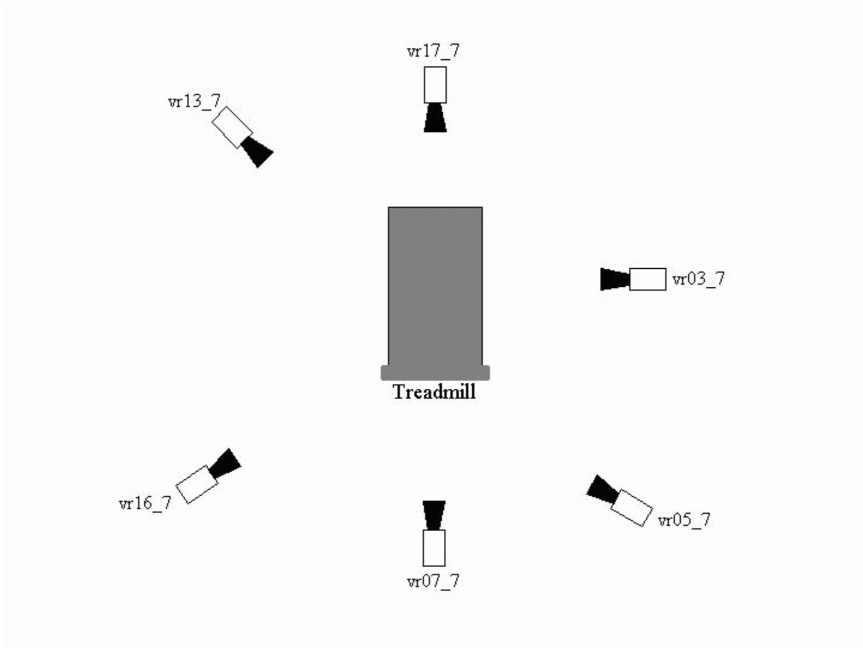

Figure 2: Camera setup in the 3D room for the data collection.

Figure 3: Panoramic view of the CMU 3D room.

2.2 Capture Procedure

We instructed each subject to wear light colored shoes to facilitate the task of segmenting the feet from the black treadmill. In order to obtain a wide spectrum of different gaits each subject had to perform four different activities on the treadmill: slow walk, fast walk, incline walk and walking with a ball. Prior to the recording the subjects were given time to accustom themselves with walking on the treadmill. Most of the subjects had no previous experience in exercising or walking on a treadmill. Nevertheless the majority of the subjects indicated that they feel comfortable walking on the device after practicing for a few minutes. The subjects were then recorded in the following order:

- *Slow walk*
  The speed of the treadmill was adjusted to be at a comfortable walking speed for the subjects. Figure 4 shows examples from all six cameras.
  Average walking speed: 2.06 mph

- *Fast walk*
  Here the directions asked for a fast but still comfortable walk.
  Average walking speed: 2.82 mph

- *Incline walk*
  The treadmill was set to the maximum incline of 15°. The speed was adjusted to be comfortable for the individual subject. Figure 5 shows example images from all views.
  Average walking speed: 1.96 mph

- *Walking with a ball*
  Finally the subjects were asked to hold a ball in front of their body while walking at a comfortable speed. The objective behind this sequence was to immobilize the arms and analyze how this affects their gait pattern. Figure 6 contains example images from all cameras.
  Average walking speed: 2.04 mph

On average the complete recording session took about 15 minutes per subject. Each sequence is 340 frames long, recorded at a speed of 30 frames per second. During this 11 second period we can typically observe about 10 full gait cycles. We record 8160 images for each subject, totaling more than 7 GB of data. At the beginning of every recording session for each subject we capture a background image with each camera to facilitate background subtraction. With 25 subjects captured the database is about 175 GB in size (uncompressed). Figure 7 shows 15 images of a fast walk sequence which spans half a walking cycle as seen from the sagittal perspective.

For each subject we also recorded a number of basic informations including: sex, age, weight, and the treadmill speed for the different walking sequences.

3 Database Organization

3.1 Available Images

We store the database in two formats: uncompressed in PPM format (175 GB) and compressed in JPG format (9.9GB). We also provide the body silhouettes for all images extracted using simple background subtraction and thresholding. Note that the extracted silhouettes are not particularly clean - silhouettes can contain holes, the silhouette boundary can be interrupted, and static background pixels can be mistakenly included. Figure 8 shows one silhouette example for each subject in the database.

Figure 4: Slow walk sequence.

Figure 5: Incline walk sequence.

Figure 6: Ball walk sequence.

Calibration information as computed using Tsai's [16] algorithm is available for all six cameras.

3.2 File Structure

The CMU MoBo database is organized as a collection of images for each subject. The subjects are identified by their unique 5-digit subject ID. For each subject the images are stored in subdirectories according to the different activities "ball", "fastWalk", "incline" and "slowWalk". The background images are kept in a separate subdirectory. In the respective subdirectories the images are further organized according to the cameras they were recorded by. The camera labels are vr03_7, vr05_7, vr07_7, vr13_7, vr16_7 and vr17_7 as shown in Figure 2. Table 2 illustrates the organization of the database.

4 Obtaining the MoBo database

Detailed instructions on how to obtain the MoBo database can be found on the HID project web page: `http://www.hid.ri.cmu.edu` under "databases".

Subject ID	Activity	View	Images
04006	ball	vr03_7	im25_03292400.ppm im25_03292401.ppm ⋮ im25_03293509.ppm
		vr05_7	
		vr07_7	
		vr13_7	
		vr16_7	
		vr17_7	
	slowWalk		
	fastWalk		
	incline		
	bgImage		

Table 2: Organization of the CMU MoBo database.

5 Usage of MoBo images in publications

We ask that only images of the following subjects are used in publications:
04002 04006 04013 04015 04071 04086

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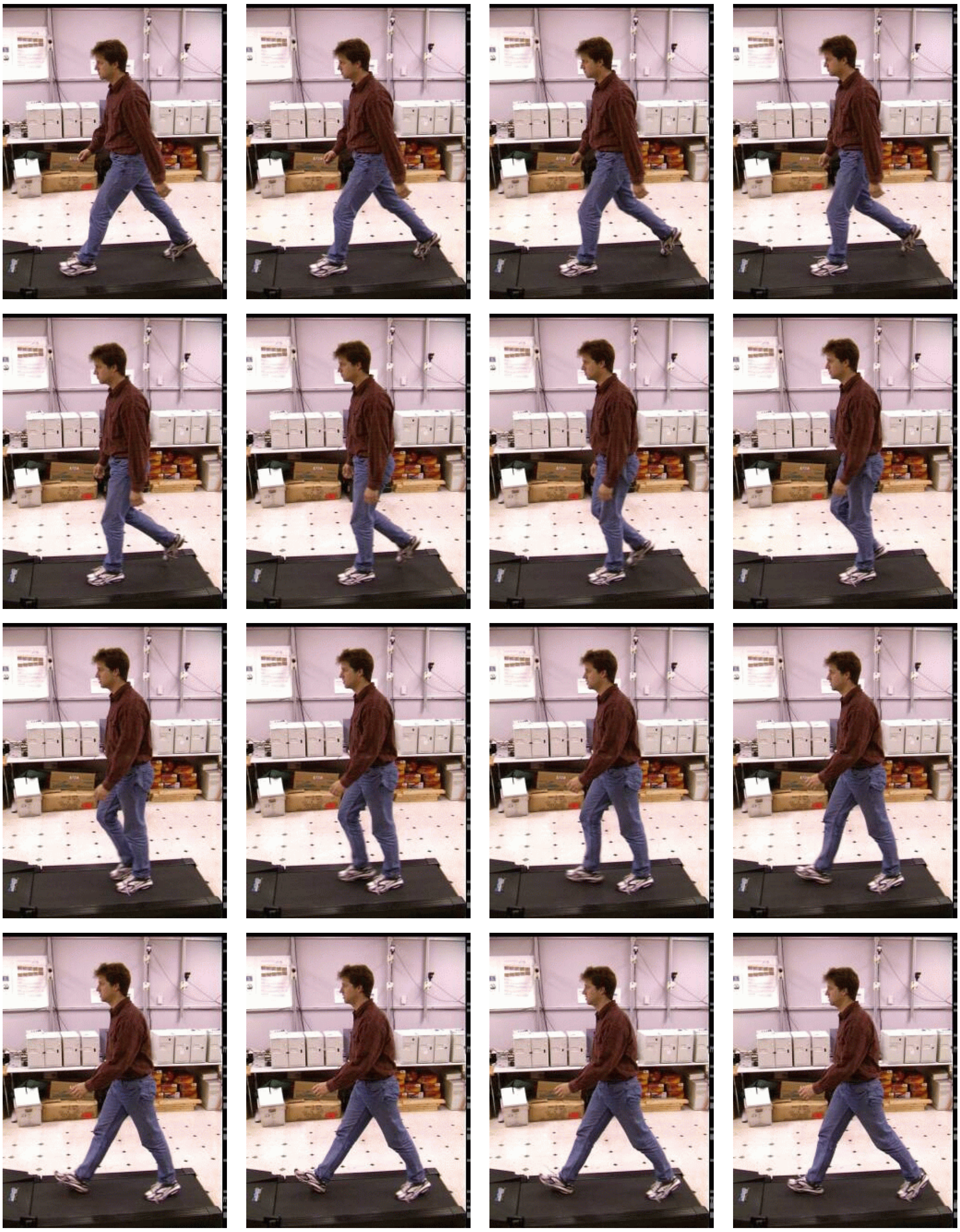

Figure 7: Half of a fast walk cycle seen from camera vr03_7.

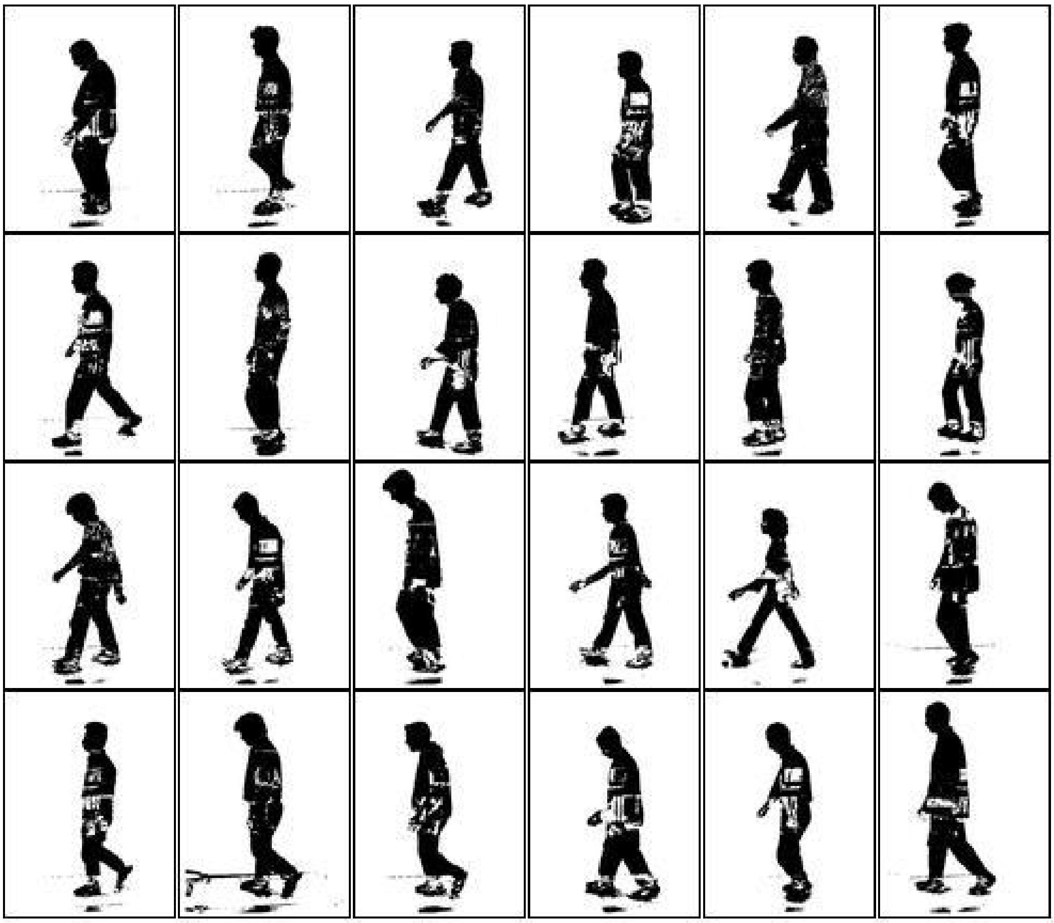

Figure 8: **The CMU MoBo database** contains six simultaneous motion sequences of 25 subjects (23 male, 2 female) walking on a treadmill. The 3CCD progressive scan images have a resolution of 640x480. Each subject is recorded performing four different types of walking: slow walk, fast walk, inclined walk, and slow walk holding a ball (to inhibit arm swing). Each sequence is 11 seconds long, recorded at 30 frames per second. More than 8000 images are captured per subject. The figure shows silhouette examples for all subjects in the database.

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