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Gait Biometrics in Interaction Design: A Work in Progress Report

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Abstract

The use of biometric data in HCI is an emerging field of science and design. In addition to the security dimension, biometrics open up new possibilities of interaction design. This paper presents suggestions on applying gait biometrics in mobile biofeedback systems. We describe a prototypical implementation of mobile gait analysis and put first ideas on incorporating gait biometrics to understand and affect subjective experiences on debate.

1 Introduction

Development and availability of a variety of sensing technologies allow more refined human-computer interaction (HCI). Capturing biometrics, biofeedback systems allow for new interaction modalities and experiences. Biometrics may be broadly defined as measurable biological and behavioral characteristics. Cast against the background of experience design, biofeedback systems are preferably applied in the area of digital games to gain insight into users' emotional and mental state (cf. Gilleade et al. 2005).

The human gait is an important source of information. Various approaches of gait analysis have been proposed to analyze gait characteristics (cf. Best & Begg, 2006). However, in HCI gait biometrics are mainly applied for authentication purposes. We investigate within our feasibility study the incorporation of gait characteristics for the purpose of mobile interaction design. In this paper we share our considerations and describe our approach of implementing a prototypical real-time gait analysis on a mobile device to gain insight into practical aspects of gait analysis.

2 Gait

The human gait is one of the most essential human activities and can be neutrally defined as follows "Human gait is a spatio-temporal phenomenon that characterizes the motion of an individual." (Chellappa et al. 2005, 2). The manner of walking reveals valuable information and plays a significant role in implicit interpersonal communication. In fact, the human gait reflects the body form, health status, activity and mood of the walking person.

Gait analysis is a means to describe observable changes of motion and thus deals with the outward aspects of the walking activity. Objectifying the information contained in a gait pattern, the scientific method of gait analysis deals with „[…] the measurement, analysis and assessment of the biomechanical features that are associated with the walking task.“ (Best & Begg, 2006, 2). There are a huge number of parameters that have been used to describe a gait pattern, most of which are temporal-spatial ones. Some characteristics commonly extracted in gait analysis, are cadence (step frequency), stride length and stance duration.

However, walking comprises more than biomechanical aspects. Qualitative gait characteristics may provide indications of a person’s inward movements. For instance the degree of gait ‚smoothness‘ (particularly applied to assess pathologically changed walking) is not only objectively measurable but also reflected in the subjective experience (Meinel et al., 2007). Investigating the relation between objectively measurable gait characteristics and the subjective experience level can make a substantial contribution towards experience design in mobile interaction. In our research we aim to understand this interplay and use the term gait gestalt (based on the German word „Gangbild“) to refer to the activity of walking as an expression of objective and subjective features.

3 Gait in Biofeedback Systems

Up to date gait analysis is primarily applied in the field of medicine and sports. Therapists apply gait analysis to recognize gait deviations and understand causes of biomechanical abnormalities in the locomotor system. Applying gait biometrics in biofeedback systems may serve different design goals. Kuikkaniemi et al. (2010) differentiate two categories of biofeedback, explicit and implicit biofeedback.

Explicit biofeedback refers to systems that incorporate biometrics to facilitate awareness of physiological processes. By means of mediation, these applications support users in training and control of unconsciously running processes (such as the galvanic skin response).

Implicit biofeedback systems make use of biometrics to support the personal manner of interaction. Depending on the user’s analyzed behavior biofeedback-based games change to a more supportive or respectively challenging mode, or vary their content (Gilleade et al. 2005). First attempts of applying gait biometrics in implicit biofeedback systems use auditory feedback to support gait characteristics such as symmetry. Prassas et al. (1997) report how music adapted to the cadence of stroke patients positively affected the symmetry of their stride length and hip joint range of motion. We aim to find indications how to affect subjective experiences by means of gait-based implicit biofeedback systems. In order to identify and measure behavioral characteristics in gait patterns (gait features), we have implemented a prototypical real-time gait analysis on a mobile device, which we describe in the following section.

4 Mobile Gait Analysis: An Approach

With the prospect of unobtrusive person identification, gait analysis on mobile devices and real-time gait feature extraction is gaining increasing attention (Derawi et al., 2010; Yang et al., 2011). We use in our gait analysis the Apple iPhone 4S[1]. The iPhone 4S has an integrated accelerometer (STMicro STM33DH) and an integrated gyroscope (STMicro AGDI)[2] for measuring translational acceleration in three axes and angular acceleration in three axes.

To allow an unobtrusive way of gait analysis, we ask users to carry their iPhone in their trouser pocket. As the orientation of the device affects the measurement, the app demands users to wear the iPhone in an upright position with the display pointed in walking direction.

4.1 Data Collection and Feature Extraction

Our current app allows users to sign up, log in and create a profile with personal data such as height, weight, gender, and age. The main functions of the app enable the recording of gait acceleration signals in a walking session and the extraction of elementary gait features in real-time. We store the measurement values acceleration, gravity, attitude, and rotation rate in a sampling rate of 100 Hz. After each session the measured data is stored in an XML file and uploaded on a server for a subsequent stationary gait analysis (offline). On the one hand, the recoding serves for analyzing gait patterns and identifying gait features; on the other hand, we use it to validate the real-time feature extraction.

The human walk is a series of steps. A periodic repetition of every two steps is defined as one gait cycle. We are able to identify gait cycles in real-time using the attitude pitch values. A pitch is a rotation around the lateral axis and indicates if the user's thigh is swinging or standing on the ground. The app identifies the moment of the human gait cycle, where the user's thigh has an angle up to 90 degrees to the ground. At that moment, the pitch signal has a distinctive peak. The app detects these peaks (see fig. 1, dashed line) and plays a sound. This first auditory feedback can be later used for time synchronization of data and video recordings and is also a first step to gait-based implicit biofeedback.

1 http://www.apple.com/iphone/

2 http://www.ifixit.com/Teardown/iPhone-4-Teardown/3130/2

In our offline gait analysis, we viewed several walking sessions from different users. These sessions varied in length, pedestrian, stop behavior, footwear, ground, and speed to get a great variety of features that influence the gait pattern. We use an approach described by Moe-Nilssen & Helbostad (2004) to identify basic gait features such as stride regularity (regularity of two consecutive steps) and cadence from the vertical user acceleration (VA) and the forward user acceleration (FA). This approach uses an autocorrelation procedure to identity these features from the VA and the FA measurement series.

4.2 Results

The identified features of the offline gait analysis serve as comparison values for the real-time gait analysis on the mobile phone. It is questionable, whether or not we are able to use the same method in our mobile approach, as the autocorrelation function requires a certain amount of repetitive measurement points in order to provide meaningful results.

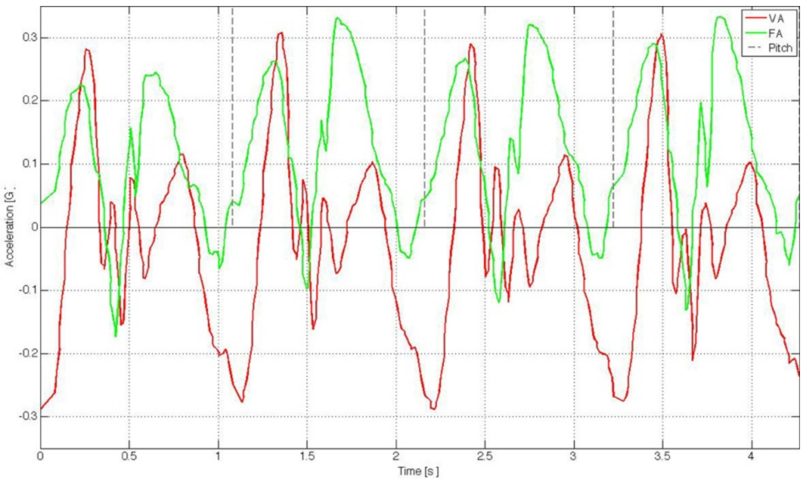

Figure 1: Gait Cycles separated by Pitch Peaks

Figure 1 shows a short part of a walking session (407 measurement points) with four pitch peaks (N) in a time interval (T) of 4.26s. The mobile approach calculates the cadence as follows:

$$C = 2\frac{60s}{\frac{T}{N}} \quad C = 2\frac{60s}{\frac{4.26s}{4}} = 112.67 \,{}^{step}\!/_{\min}$$

The offline approach calculates for the same data set a cadence of 108.09 steps/min. If we include more gait cycles (11 cycles, 986 measurement) the mobile approach calculates the same cadence value as before. In contrast the result of the offline approach changes to a cadence of 110.43 steps/min and approaches the mobile result. Thus, the use of the gyroscope in mobile gait analysis is more promising than the sole use of an accelerometer (cf. Lee & Park 2011). Currently, we identify only a moment of the human gait cycle, but the detection of pitch peaks in real-time is our first step in the field of mobile gait analysis.

5 Outlook

In the further course of our research we will deepen technological and theoretical aspects of gait-based biofeedback.

Implementing a mobile gait analysis, we created the prerequisite to examine gait gestalt and its meaning in mobile interaction design. In the continual development process we will integrate a global reference coordinate system to ignore the orientation of the device and reduce the distortion that will emerge when the device moves in the trouser pocket. Furthermore, we have to improve the detection of maxima and minima in the gyroscope and acceleration data to optimize the feature extraction. We will apply our mobile application to analyze context-related changes of gait features and understand the relation of contextual characteristics and the gait gestalt. In particular we will investigate how a person's gait gestalt reflects the following contextual characteristics such as a) emotional state, b) location/place and c) activity.

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