My Personal Trainer - An iPhone Application for Exercise Monitoring and Analysis

Christopher R. Greeff[1] **Joe Yang**[1] **Bruce MacDonald**[1]
Burkhard C. Wünsche[2]

[1] Department of Electrical and Computer Engineering
University of Auckland, New Zealand,
Email: chizzajt@gmail.com, lyan101@aucklanduni.ac.nz, b.macdonald@auckland.ac.nz

[2] Graphics Group, Department of Computer Science
University of Auckland, New Zealand,
Email: burkhard@cs.auckland.ac.nz

Abstract

The obesity epidemic facing the Western world has been a topic of numerous discussions and research projects. One major issue preventing people from becoming more active and following health care recommendations is an increasingly busy life style and the lack of motivation, training, and available supervision. While the use of personal trainers increases in popularity, they are often expensive and must be scheduled in advance. In this research we developed a smartphone application, which assists users with learning and monitoring exercises. A key feature of the application is a novel algorithm for analysing accelerometer data and automatically counting repetitive exercises. This allows users to perform exercises anywhere and anytime, while doing other activities at the same time. The recording of exercise data allows users to track their performance, monitor improvements, and compare it with their goals and the performance of other users, which increases motivation. A usability study and feedback from a public exhibition indicates that users like the concept and find it helpful for supporting their exercise regime. The counting algorithm has an acceptable accuracy for many application scenarios, but has limitations with regard to complex exercises, small number of repetitions, and poorly performed exercises.

Keywords: accelerometer, activity monitoring, signal processing, exercise performance, fitness application, human-computer interfaces

1 Introduction

The worldwide prevalence of obesity has almost doubled between 1980 and 2008 and has reached an estimated half a billion men and women over the age of 20 (World Health Organization 2012). Exercises help to fight obesity, but are often not performed due to lack of motivation (American Psychological Association 2011). Motivation can be increased by enabling users to self-monitor and record exercise performance and to set goals. For example, an evaluation of 26 studies with a total of 2767 participants found that pedometer users increased their physical activity by 26.9% (Bravata et al. 2007).

In this research we present an iPhone based "personal trainer" application, which assists users with performing exercises correctly, self-monitoring them, and evaluating performance. A key contribution is a novel algorithm for counting repetitive exercises. This helps users to easily keep track of daily exercise data, and encourages them to perform simple exercises frequently, e.g., during work breaks and recreational activities.

2 Design

2.1 Software Architecture

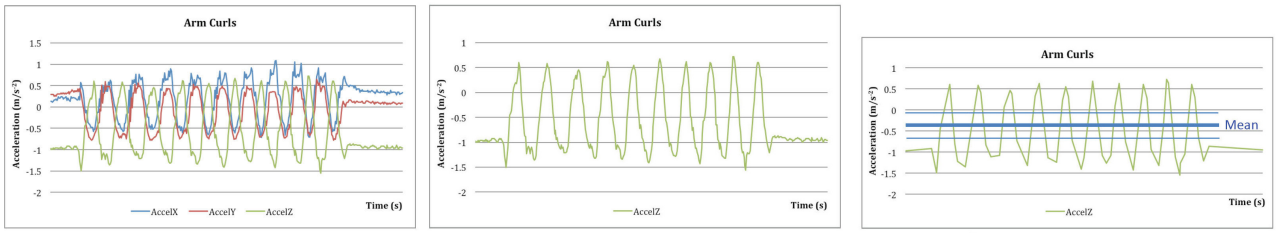
The application is designed with a three tier architecture. The presentation tier of the application consists of two parts: The exercise view gives feedback to the user while performing exercises, whereas the data view is used for planning and monitoring exercises and provides instructions and visualisations of recorded data. The repetition counter generates information about user performance based on the selected exercise and an analysis of accelerometer data. The database manager is responsible for saving and retrieving information (e.g., educational material and exercise performance data).

2.2 User Interface & Functionalities

Users can choose a predefined exercise or define a new exercise. Each exercise has a short name used in the monitoring application, an image and/or video explaining the exercise, and a short description of it including where the iPhone should be attached to the body in order to record repetitive motions. After an exercise is selected a *counting view* is shown. The user must attach the iPhone to the body part to be moved during the exercise. Some exercises require a body position, which makes it cumbersome to press the `Start` button directly before an exercise. We hence added a short 5 second countdown during which the user can get prepared for the exercise. A beep sound indicates to the user that the counting application is ready.

2.3 Counting Algorithm

The number of repetitions of an exercise is determined using the algorithm illustrated in figure 1. The algorithm works satisfactory for exercises with smooth consistent motions (e.g., arm curls or side raises), but problems occur for exercises prone to shaking and jerking (e.g., lunges). Even after simplification with the Douglas Peucker algorithm, the data can contain large variations and sudden jumps which will result in inaccurate counting. We reduced this problem by



(a) Raw accelerometer data (b) Coordinate with maximum standard deviation (c) Smoothed data and mean

Figure 1: The steps of the counting algorithm: (a) Raw accelerometer data of a user performing ten arm curls with the iPhone strapped to the lower arm. (b) Acceleration coordinate with the largest standard deviation. (c) Data after simplification with the Douglas Peucker algorithm and computing the mean value and standard deviation of its sample points. The number of repetitions is computed as the number of cycles with sections below the threshold $(\mu - \sigma)$ followed by a section above the threshold $(\mu + \sigma)$. The above graph represents 10 repetitions of arm curls.

additionally requiring that the cycle time (distance between peaks and valleys) is above 0.5 seconds and moderately regular, i.e., very short and very long cycles are not counted. This restriction is acceptable since an interview with an exercise therapist confirmed that exercises are most useful when performed with a smooth moderate motion.

3 Results

3.1 Methodology

We performed a user study involving 20 participants aged $16-60$ years. Exercise frequency ranged from $1-2$ hours to $5-10$ hours of exercises per week. To test the counting algorithm of our application we asked participants to perform $5-10$ repetitions of the following exercises: arm curls, side raises, push-ups, squats, lunges and a customised exercise that users defined themselves and added to the application. The low number of repetitions resulted from several users being untrained and hence having problems performing more than 5 push-ups. Our original plan to have 20 repetitions for each exercise proved unrealistic.

All tests were conducted without extra weights, e.g., arm curls and side raises were performed without holding a dumbbell. We used an iPhone armband/waistband to attach it to different body parts. We observed the participants and counted the number of repetitions, and compared it with the number of repetitions recorded by the algorithm. We then computed the measurement accuracy as percentage variation from the actual count.

3.2 User Study Results

The overall accuracy, including customised exercises, was over 80%. The exercise with the highest accuracy, averaging roughly 95%, was the arm curl and the side raise. The exercise with the lowest accuracy, averaging roughly 55%, was the lunge exercise. The push up, squat and custom exercise averaged roughly 80%. A closer examination of the results revealed that two problems occurred: The counting algorithm often had problems detecting the first and last repetition of an exercise, especially for exercises containing complex motions, or exercises which were physically difficult. As a consequence the measured count was frequently 1-2 repetitions too low. For exercises, such as push-ups, where some users achieved only 5 repetitions, this resulted in an error of 20-40%. The second problem was related to the smoothness of the performed exercise. The algorithm works best for simple motions where users can easily get into a "rhythm". In such cases an accuracy of 98% was achieved.

Overall users were satisfied with the design and information content of the application. Users regarded the application as only moderately useful, but slightly more than half of the participants could imagine to download and use the application, if available. Subsequently we presented the application at a public display in the university. The visitor feedback was overwhelmingly positive and several visitors were keen to buy the application on the Applet app store.

4 Conclusion & Future Work

We have presented a novel iPhone application assisting users with getting physical active by providing information on simple exercises, and automatically recording exercise performance. A key contribution is a novel algorithm for analysing accelerometer data in order to detect the number of repetitions in an exercise performance.

A user study confirmed that the algorithm is satisfactorily accurate for simple smooth motions and high number of repetitions. Problems exist for complex motions, exercises with a very low number of repetitions, and exercises performed with jerky and irregular motions.

More work needs to be done to make the presented prototype useful in practice, and in particular to achieve behavioral change. The counting algorithm needs to be improved to make it work for a larger range of exercises, and to make it more stable with regard to low number of repetitions and irregular and jaggy motions. Usability and motivation could be improved by adding voice activation and feedback. A controlled long term study is necessary to measure behavioural change, such as more frequent or longer exercises when using the application.

References

American Psychological Association (2011), 'Stress in america findings'. `http://www.apa.org/news/press/releases/stress/national-report.pdf`, Last retrieved 25th August 2012.

Bravata, D. M., Smith-Spangler, C., Sundaram, V., Gienger, A. L., Lin, N., Lewis, R., Stave, C. D., Olkin, I. & Sirard, J. R. (2007), 'Using pedometers to increase physical activity and improve health: A systematic review', *JAMA: The Journal of the American Medical Association* **298**(19), 2296–2304.

World Health Organization (2012), 'World health statistics 2012'. `http://www.who.int/gho/publications/world_health_statistics/EN_WHS2012_Full.pdf`, Last retrieved 25th August 2012.