Bringing mobile guides and fitness activities together: a solution based on an embodied virtual trainer

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ABSTRACT

Sports and fitness are increasingly attracting the interest of computer science researchers as well as companies. In particular, recent mobile devices with hardware graphics acceleration offer new, still unexplored possibilities. This paper investigates the use of mobile guides in fitness activities, proposing the Mobile Personal Trainer (MOPET) application. MOPET uses a GPS device to monitor user's position during her physical activity in an outdoor fitness trail. It provides navigation assistance by using a fitness trail map and giving speech directions. Moreover, MOPET provides motivation support and exercise demonstrations by using an embodied virtual trainer, called Evita. Evita shows how to correctly perform the exercises along the trail with 3D animations and incites the user. To the best of our knowledge, our project is the first to employ a mobile guide for fitness activities. The effects of MOPET on motivation, as well as its navigational and training support, have been experimentally evaluated with 12 users. Evaluation results encourage the use of mobile guides and embodied virtual trainers in outdoor fitness applications.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces—*Evaluation/methodology, Graphical user interfaces (GUI)*; I.3.6 [**Computer Graphics**]: Methodology and Techniques—*Interaction techniques*; I.3.7 [**Computer Graphics**]: Three-Dimensional Graphics and Realism—*Animation*

General Terms

Human factors, Experimentation

Keywords

Mobile guides, virtual trainers, embodied agents, fitness applications, user evaluation

1. INTRODUCTION

Scientific evidence shows that the regular practice of physical activity and sports provides people of all ages and conditions with a wide range of physical, social and mental health benefits. Physical activity interacts positively with diet, enhances functional capacity and promotes social interaction and integration. Physical activity also has economic benefits especially in terms of reduced health care costs, increased productivity, healthier physical and social environments. In particular, open-air physical activity is characterized by additional valuable aspects, such as natural environments, air quality and sunlight. On the contrary, physical inactivity is a common and preventable risk factor for some chronic diseases.

Computer science researchers as well as companies are devoting an increasing attention to sports, fitness and physical activities. The developed products fall in three categories:

- computer-supported physical games [13, 14, 17];
- virtual trainers [16, 22, 23];
- mobile applications and devices for physical activities [3, 4, 6, 10, 11, 18, 21, 24].

The third category is very promising because it could allow users to be assisted anytime, anywhere. However, the user interfaces of current commercial products are extremely limited and do not focus much on user's motivation. To overcome their limitations and help users in performing fitness exercises correctly, this paper proposes MOPET, a mobile guide that employs a 3D virtual fitness trainer, called Evita. An alternative to virtual trainers consists in filming a real trainer performing the exercises and then displaying the videos on the mobile device. Anyway, using 3D animations presents several advantages with respect to pre-recorded videos: (i) 3D animations can be interactively explored by the user, who can easily change views and watch the exercise from the angles and positions that can clarify her personal doubts, and (ii) animations require much less space than videos on the mobile device.

At present, our mobile guide is designed to help users in fitness trail sessions. A fitness trail is a trail where the user has to alternate jogging and exercising. The user runs along an indicated path and has to stop when she arrives at an exercise station. In each exercise station, the user finds an exercise tool that she has to use to perform a specific fitness exercise. MOPET helps users in:

- Navigation: location-aware audio and visual navigation instructions are provided to allow the user to follow the correct path in the fitness trail.
- Motivation: audio and visual feedback of user's speed are provided. The feedback motivates the user to maintain an adequate speed during all the session, according to her feelings.
- Training: when the user reaches an exercise station, Evita shows how to correctly perform the exercise.

The paper is organized as follows. Section 2 surveys related work on computer-aided physical exercise. Section 3 describes in detail the features of our mobile guide. Section 4 and 5 describe the experimental evaluation we carried out and report about the results we obtained. Finally, Section 6 provides conclusions and outlines future research directions.

2. RELATED WORK

2.1 Computer-supported physical games

Chi et al. [7] have provided a state of the art of pervasive computing in sport technologies, with the aim to encourage new research in this emerging area and to describe how technology can be applied to sports. They identify three areas of application - athletic performance, entertainment and support for referees - pointing out some research lines for each, such as studying which sensors are more appropriate to monitor the performance of different kinds of athletes and studying the use of games and special equipment to encourage users to exercise harder.

An example of a game that encourages users to exercise harder is Shadow Boxer [14]. In this game, user's body movements control an avatar that has to hit the objects which appear on the game window, using the fitness boxing basic movements, which include three different kinds of punches. User's body movements are detected using a common webcam. The authors evaluated the game on 11 users, proving that it can significantly increase user's heart rate and keep it at the optimal level for the exercise.

Another user evaluation that shows the effectiveness of adopting a game-style to encourage physical activity was carried out by Hämäläinen et al. [13]. They describe a martial arts game in which the user has to fight virtual enemies with punches, kicks and acrobatic moves. User's image and movements are acquired through a camera and embedded into a 3D world projected on two screens. To add fun, the game can exaggerate user's jumps and use slow motion for her acrobatic moves. The game was informally tested in a theater and in a television show to understand its entertainment value. To investigate educational and fitness value, a more formal test with 46 martial arts practitioners was organized. The interviews showed that experts as well as novices, prefer motion exaggeration, while heart rate measurements showed that the game can be used for fitness purposes, since the median of users' heart rates after fighting an enemy was at 90% of their median maximum heart rate and values between 70% and 90% are recommended for fitness training.

Jeong et al. [17] concentrated instead on the use of force and touch feedback in a system which combines an immersive virtual environment with a human-scale haptic interface. In particular, the system was applied to a Virtual Catch Ball game, with the aim of achieving a deeper interaction and a stronger sense of presence of the virtual human the user plays with.

2.2 Virtual trainers

Although the general benefits of embodied agents in user interfaces have been already described several years ago [1, 2, 19], their use as virtual trainers is still scarcely explored. A pioneering evaluation of a 2D trainer for fitness purposes can be found in [16], where the Philips Virtual Coach system is used to motivate the user while she cycles on a stationary home exercise bike. The coach is projected on a screen, which also shows a virtual immersive environment representing an open-air landscape. By studying 24 users, the authors showed that the immersive environment offers fun and has a beneficial effect on motivation, while the virtual coach did lower perceived pressure and tension. The authors noticed also some negative effects of the coach on perceived control, possibly due to the information provided by the coach rather than the coach itself. Indeed, the coach provides the user only with information about her heart rate, instead of motivating her by reporting the calories she burnt or talking about other benefits of the physical activity.

Embodied virtual trainers are used also in commercial applications for PCs and gaming consoles. For example, Yourself!Fitness [22] includes a 3D virtual trainer that can suggest the user a set of exercises varying upon user's focus (weight loss, cardio, body strength). The trainer can also show how to perform an exercise correctly and motivate the user in following the fitness program. However, the user interacts with the game only with a common joypad and the system cannot determine whether she is working well or just sitting.

On the contrary, EyeToy:Kinetic [23], a fitness application for Playstation 2, detects user's movements through the EyeToy camera, a cheap device similar to a webcam. The application lets the user choose a personal trainer that creates for her a specific 12-week plan, taking into account user's height, weight, age, familiarity with EyeToy games and physical condition (thanks to a short questionnaire). The application adopts a game style, aiming at transforming martial arts, Tai Chi and cardio exercises into entertainment. During the games, the user is monitored to determine her score and give her suggestions on how to perform the exercise better. The 3D virtual trainer comments game, day, week and month performance giving the user an "E" to "A+" mark and congratulating her for the results or encouraging her to keep training and further improve. However, since EyeToy:Kinetic uses a single camera, it can recognize only movements on a 2D plane, severely limiting the set of possible users' actions.

2.3 Mobile applications for physical activities

All the solutions described in the previous sections are meant for indoor use. Therefore, they prevent the user from getting the benefits of open-air physical activity, such as jogging in natural environments. To help people in open-air physical activities, some researchers [3, 6, 18] and companies [4, 10, 11, 21, 24] proposed mobile solutions.

Human Pacman [6] is an interactive role-playing mobile game in which one user (Pacman) physically walks on a trail to grab some virtual cookies and some actual physical objects, while other users (Ghosts) try to catch her. The game was not designed for fitness purposes, but it was one of the first games that explored the combination of entertainment with wearable computer and motivates users to move to improve their score. Human Pacman uses several sensors (e.g., GPS, Bluetooth devices, FireWire camera) to monitor user position and interaction with the objects on the trail. Moreover, to enhance immersion, users wear head mounted displays, through which real and virtual world elements are mixed.

To monitor user's life-parameters (e.g., heart rate, temperature) during physical activities, Knight et al. [18] proposed the SensVest, a wearable device that can measure user's heart rate, body temperature and acceleration and send them to a remote computer. SenseWear Armband [4] is a commercial product similar to the SensVest. While the SensVest is integrated in a shirt, the SenseWear Armband can be worn on the upper right arm and collect also heat flux and galvanic skin response, but heart rate measurement is a feature still in development.

Polar heart rate monitors [21] are other commercial mobile devices to monitor user's parameters during physical activities. Besides measurements, Polar devices can give a basic motivational feedback, called "calorie bullet": every time a certain amount of calories is burnt, the device beeps, inciting the user to run more and burn other calories. After a training session, some Polar devices allow the user to transfer her data to a PC and send them to Polar on-line services, that can better analyze her performance. Moreover, Nokia 5140 phones are provided with a Polar Java application that connects to a Polar sensor. The application allows the user to plan and keep track of her physical activities, but since heart rate data can be sent via infrared only after the user has completed the training session, real-time data analysis is not possible.

FRWD [10] overcame the connection limitation with a Bluetooth real-time transmission between FRWD Recorder Unit (a GPS mobile device that monitors users' position and heart rate) and FRWD Mobile Player (an analysis software for recent Symbian phones). This allows the user to have her data (heart rate, position, altitude, speed, route) constantly analyzed.

Garmin Forerunner 305 [11] is a GPS receiver that can monitor heart rate and display information about the on-going physical activity. Anyway, the screen can only show numerical data, while post-workout analysis requires a PC with Garmin Training Center software.

Mobile graphical analysis of users' parameters, training planning and 2D illustration of exercises are supported by VidaOne MySportTraining [24]. However, this PDA application can acquire heart rate data only from Polar devices via infrared, carrying out the analysis at post-training time, so it cannot provide the user with real-time motivation.

Asselin et al.'s Personal Wellness Coach [3] is the only real-time and partially mobile virtual motivator we found in the literature. This wearable system uses a BodyMedia SenseWear Armband and a Polar device respectively to track user's movement and monitor heart rate. To use Polar data in real-time, the authors built a custom board that can wirelessly and constantly send both BodyMedia and Polar data to a laptop that can be up to 9 meters away. The system can prevent harm, warn of overexertion, and motivate the user, providing her with interactive audio and music feedback. Anyway, the need for a laptop limits the application area of Personal Wellness Coach: for example, mobile physical activities, such as outdoor running, cycling and exercising on fitness trails, cannot be supported.

3. OUR PROPOSAL: MOPET

Since we aim at guiding and motivating users in outdoor fitness activities, we designed and implemented MOPET, a mobile guide which includes an embodied virtual trainer, called Evita. MOPET runs on PocketPCs connected to a GPS device. To the best of our knowledge, MOPET is the first mobile guide for fitness activities.

The mobile solutions described in Section 2.3 offer extremely limited interfaces: most of them follow a digital-clock style that can provide only scarce motivational support. To overcome this limitation, in our solution we included an embodied agent that can attract user's attention and can convey additional conversational and emotional cues [1, 2, 19].

Figure 1: 3D animation introducing the user to the application.

Our mobile guide is designed to support the user in her physical activities, providing her with audio navigation assistance, audio and graphical feedback about her speed and 3D demonstrations of the exercises depending on her current position. At present, MOPET supports the user in outdoor fitness trails. This section presents the main functionalities of our mobile guide.

3.1 Navigation

When the user starts MOPET, Evita introduces herself with a 3D animation (Figure 1). Then, a map of the trail where the user is training is displayed on the screen of the PDA and Evita briefly describes the map, the icons on the map, and how the application works (if the user is already familiar with MOPET, she can skip this introduction).

On the map, user position is marked with an icon representing a running person. Other icons are used to mark checkpoints: the start-finish (a chequered flag), the fitness trail exercise stations (a person performing an exercise), the points where the trail forks (a compass) and additional points where MOPET tells the user her speed (a red triangular flag). Besides, the trail is marked with a polygonal line which is initially blue.

MOPET provides common navigational cues, such as changing the user's position in the map based on the data retrieved from the GPS device and changing the color of the polygonal lines to indicate the completed parts of the trail. Figure 2 shows the map after the user completed the left half of the trail. Anyway, this graphical feedback can be easily examined only by a user who is not running and so we provide the user also with audio navigational information: when she approaches a fork, MOPET gives her vocal directions using the internal speaker of the PDA.

Figure 2: Map status with the left half of the trail completed.

3.2 Motivating the user

While navigation support is a common feature of mobile guides, fitness motivation on mobile devices has not been sufficiently explored yet, as discussed in Section 2. Moreover, a simple porting of desktop or console solutions is not possible or suitable: on one hand, mobile devices suffer of hardware limitations and user's activity may prevent her to constantly look at the device; on the other hand, these devices are capable of providing context-aware information, that may be used for motivational purposes.

Our mobile guide exploits contextual information and offers motivation using both the graphical and audio channels. The application calculates average user's speed on the different parts of the trail. After consulting a sports physician, we divided speed into four ranges: slow walking (< 5 km/h), fast walking (5-8 km/h), moderate running (8-12 km/h) and fast running (> 12 km/h). The lines corresponding to different parts of the trail are colored according to a blue-red temperature scale, giving the user visual feedback about her speed.

To provide the user with immediate audio feedback, Evita tells the user her current range of speed and incites her to increase or decrease her speed, as soon as a checkpoint is reached. For each speed range, different pre-recorded sentences are available to the virtual trainer. All sentences are not imperative and try to highlight positive aspects of user's performance, even if she walked very slowly (e.g., "You are walking regularly. If you are not tired, try to increase your speed."). We chose to incite users gently because the evaluation results of Philips Virtual Coach [16], which incites aggressively (e.g., "Your heart rate is slow! Run faster!"), were not as positive as expected.

Figure 3: Evita performing a typical exercise with rings on a fitness trail.

3.3 Training

Besides motivating the user, Evita gives location-aware exercise demonstrations. As the user approaches a fitness trail exercise station, Evita firstly whistles to attract user's attention and invites the user to look at the PDA display, then demonstrates how to correctly perform the exercise with a 3D animation. For example, in Figure 3, it is performing an exercise with rings.

In fitness trails, exercises are usually explained by using illustrated plates in the stations. These plates are often not easy to understand and the exercise could be performed improperly, wasting the benefits of the physical activity and also risking injuries. For example, after watching the metal plate in Figure 4, the user can make mistakes such as: (i) not keeping the feet on the ground; (ii) moving the pelvis left and right, but not in circles; (iii) moving the pelvis only clockwise or only counterclockwise. Therefore, while demonstrating the exercise, Evita explains how to perform it correctly and safely.

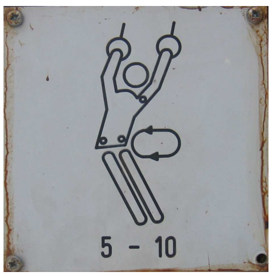

Figure 4: Metal plate of a fitness trail exercise

3.4 Implementation details

MOPET has been implemented in C# using Microsoft .Net Compact Framework 2.0. Evita is a 3D embodied agent that complies with the X3D [25] and H-Anim [15] standards. Animations were modeled with our H-Animator tool [5] and played on the PDA with our MobiX3D player [20]. The fitness trail map used in our tests was built by georeferencing a satellite photograph taken from Google Earth [12].

4. EXPERIMENTAL EVALUATION

The evaluation has been carried out in the fitness trail of a public park. The trail is 1110 meters long and has 6 fitness stations. At each station, the runner can perform a different physical exercise using a specific wood and metal tool. On each tool a metal plate illustrates how to perform the exercise.

4.1 Subjects

Twelve users, 7 male and 5 female, took part in the evaluation. Their age ranged from 20 to 35, averaging at 24. One of them was an office employee, while the other subjects were university students from different faculties. Only 4 of them engaged frequently in physical activities. Only one of them had tried the fitness trail before. Finally, only 2 of them had used a PDA before.

4.2 Hardware

The evaluation was carried out with a Dell Axim X50v. Power saving features were disabled to provide maximum performance. The PDA was equipped with a 624 MHz CPU with 64 MB of main memory, an Intel 2700G graphics processor with 16 MB video RAM, and a Compact Flash GPS card. Audio was delivered by the internal speaker. The PDA was worn using a wristband.

4.3 Design and Procedure

Each subject was asked to go through the entire fitness trail. Following a within-groups design, every subject carried out the task twice: once with and once without the mobile guide. When the user had to complete the task without the mobile guide, she had to use the maps sticked on the wood panels she found in the fitness trail to orient herself, and the illustration plates in the stations to understand how to perform the exercises. When using MOPET, users were asked to ignore the trail maps and the illustration plates, and rely on the mobile guide. We filmed the users from a distance while they were doing two particular exercises of the trail. Moreover, we tracked users' position in the park, once by using MOPET and once by using a simple GPS position logging application, which did not provide any information to the user. Therefore, we asked users to wear the PDA during both sessions.

Subjects were initially asked to fill a demographic questionnaire (age, sex, PDA experience, physical activities frequency). They were then led at the beginning of the fitness trail and told about the task. During the test, they wore the PDA running MOPET or the simple position logging application. On average, the time needed to complete the tasks for each subject was around 45 minutes.

4.3.1 *Evaluation of navigation support*

Since each user had to complete the fitness trail twice, we asked users to run once clockwise and once counterclockwise to limit navigational learning effects. Half of the users tried MOPET the first time and then tried the maps on the trail, while the other half used first the maps and then MOPET.

Before starting the test without our guide, subjects were led to the fitness trail map nearest to the start. They could look at the map all the time they needed before starting to run. Moreover, they could look at the maps located in different areas of the trail, if they were in doubt about the path to follow.

As users started the test with the mobile guide, they went through a very short presentation lasting about 1 minute. In the presentation, the embodied agent introduced itself and then described the elements of the interface. MOPET guided the user with speech directions and displayed a map with user's position and completed parts of the path colored as described in Section 3.2.

To evaluate navigation support, we analyzed users' GPS logs with the VU-Flow visual tool [9] to observe how much users ran in the right trail or took paths which lead away from it. We considered a user out of the trail when she ran for more than 5 meters on a path which did not belong to the trail. The following dependent variables were measured:

- number of times the user followed paths that lead away from the trail;
- meters run out of the trail;
- meters of the trail the user skipped;
- percentage of time the user spent on other paths.

Finally, a questionnaire was administered to collect data about subjective impressions and preferences: users were asked to give a vote on a 5-values Likert scale (where higher values corresponded to better ratings) to the usefulness of the fitness trail maps and of our mobile guide. They could also freely write comments and suggestions.

4.3.2 Evaluation of motivation support

As described in Section 3, Evita incited users telling them how fast they were walking or running and inviting them to stop at the stations to perform the exercises. Moreover, the MOPET map displayed the completed parts of the trail using a color which changed with users' speed, as described in Section 3.2. To evaluate the effectiveness of the motivation support, we administered a questionnaire. We asked the users how much MOPET motivated them and whether they would come more frequently to the fitness trail if they could use MOPET.

4.3.3 Evaluation of training support

To evaluate the training support, we filmed users from a distance while they were performing exercises at trail stations after watching Evita performing the same exercise in 3D or after looking at the metal plates that can be found in each station. To avoid learning effects the users performed two different exercises of the same difficulty. Half of the users performed an exercise with rings using Evita and an exercise with a horizontal bar using the metal plates, while the other half used Evita for the bar and the plates for rings. Each filmed performance was evaluated with a score between 0 and 4.

For the exercise with rings, the score was determined according to the following considerations:

- the user moved the pelvis correctly (up to 1.5 points);
- she kept correctly the feet on the ground (up to 1.5 points);
- she moved the pelvis both clockwise and counterclockwise (up to 0.5 points);
- she understood how to perform the exercise correctly in 10 seconds or less, after watching the animation (or the plate) for the first time (up to 0.5 points).

For the exercise with the horizontal bar, the score was determined according to the following considerations:

- the user pushed up the bar (up to 2 points);
- she kept the back upright (up to 1 point);
- she understood how to perform the exercise correctly in 10 seconds or less, after watching the animation (or the plate) for the first time (up to 1 point, since understanding this exercise is more difficult than understanding the one with rings).

Moreover, we asked the user to rate the usefulness of Evita training animations and of the metal plates on a 5-values Likert scale.

5. RESULTS

To analyze the four dependent variables described in Section 4.3.1, we employed Wilcoxon's matched-pairs two-tailed test, since we could neither assume a normal distribution nor a priori hypothesize what condition could be better than the other. Only 2 users made one error using MOPET, while 8 users made one error using fitness trail maps, so the mean number of errors with the mobile guide was 0.17, while the mean was 0.67 with the maps ($p=0.02$). MOPET is significantly better than maps also in terms of meters run out of the trail and meters of trail skipped: the mean for the former variable was 7.92 m with MOPET and 298.33 m using maps ($p=0.02$), while the mean for the latter variable was 5.42 m with MOPET and 129.58 m with maps ($p=0.02$). The difference is statistically significant also for the percentage of time spent outside the trail (Figure 5): the mean was only 0.60% for MOPET, while it was 17.80% for maps ($p<0.01$).

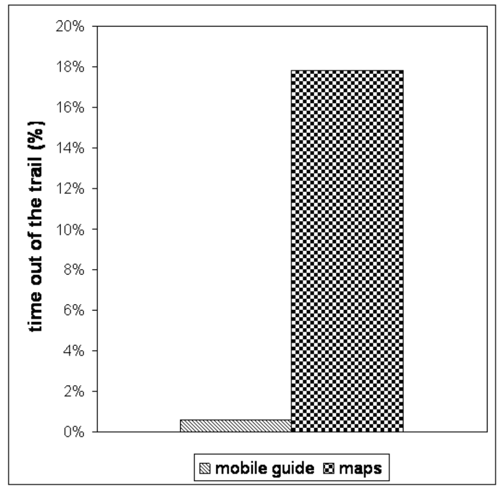

Figure 5: Percentage of time out of the trail (means).

Users' subjective impressions are consistent with the previous results (Figure 6): the mean of users' ratings on perceived usefulness was 4.08 for MOPET, while it was only 1.75 for trail maps. Wilcoxon's matched-pairs two-tailed test pointed out that the effect was significant ($p<0.01$).

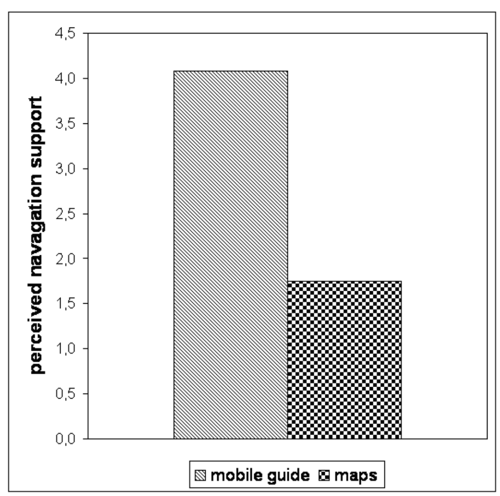

Figure 6: Perceived usefulness of MOPET and trail maps (means).

For motivation support, the mean of users' ratings was 3.33 on the 5-values Likert scale for the question asking how much Evita motivated them. The mean was 3.33 also for the question asking whether they would come to the trail more frequently if they could use MOPET.

Following the scoring criteria described in Section 4.3.3, the mean score for the exercises that were illustrated by Evita was 3.08 out of 4, while the mean score for the exercises illustrated by the metal plates was only 0.92 (Figure 7). With metal plates, two typical errors made by users consisted in not understanding they had to push up the horizontal bar and not keeping feet on the ground while moving the pelvis during the exercise with rings. Wilcoxon's matched-pairs two-tailed test pointed out that the effect was significant (p=0.04). There was a statistically significant difference also for questionnaire results (Figure 8): the mean of perceived usefulness for the training based on the mobile guide was 3.17, while the mean for metal plates was 1.33 (p=0.01).

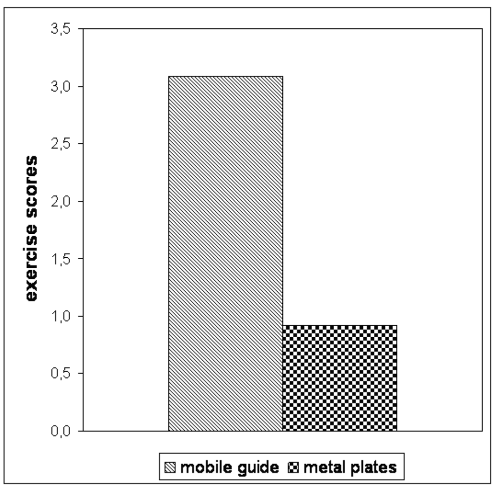

Figure 7: Exercise scores (means).

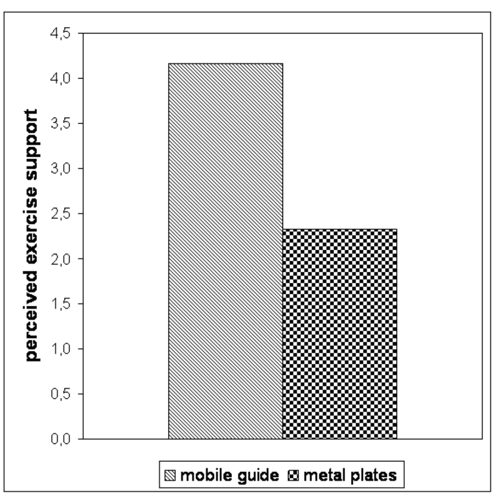

Figure 8: Perceived usefulness of Evita animations and metal plates (means).

Users wrote also several comments and suggestions. For example, most of them said that the volume was too low and the screen was not bright enough. The audio problem could be solved using a Bluetooth earphone, since the internal speaker volume was at the maximum level, but the wristband case attenuated the sound. Brightness was set to the maximum level, but the wristband transparent case reflected sunlight. There were other issues with the wristband: some users suggested to wear the PDA on the upper arm or on the belt. Some users also asked for more precise directions and positioning information (e.g., "go straight for 3 meters") which cannot be provided due to the insufficient precision of GPS.

Considering interaction aspects, users' suggestions can be subdivided in three categories: navigation improvements, auditory information and new motivation features. Some users suggested to use a self-orienting map, others would have liked a more detailed map that could zoom on the area where they were, together with a smaller and less detailed map of the whole park (i.e. an overview+detail approach). Finally, some users thought the mobile guide should have given them positive or negative feedback when they took or missed the right path.

As discussed in Section 3.2, we chose a gentle voice for Evita, but some users would have liked an even more gentle one. Finally, two users suggested us to play music when there are no instructions to give. Other suggested features concerned burnt calories and previous training session times.

6. CONCLUSIONS AND FUTURE WORK

This paper investigated the use of a mobile guide (called MOPET) for outdoor fitness activities. At present, MOPET provides navigation, motivation and training support in fitness trail sessions. MOPET includes an embodied virtual trainer called Evita for motivating the users and showing how to correctly perform the exercises. To the best of our knowledge, MOPET is the first mobile guide for fitness activities.

We evaluated the effect of our mobile guide on users' motivation as well as its navigation and training support on 12 users. We analyzed GPS logs, questionnaires and videos of users' performance, which showed that MOPET is more useful than fitness trail maps for helping users to orient themselves in a fitness trail. Our mobile guide is also more effective than metal plates for learning how to correctly perform exercises.

Our research will proceed in several directions. First, we will try different kinds of facial animations and pre-recorded sentences for users' motivation and study users' reactions. Second, we will monitor users' heart rate and the guide will give suggestions also based on this parameter. Third, we will implement and test different kinds of navigation aids and we will include positive/negative feedback when the user takes/misses the right path. Fourth, we will look at wearable devices that could be more comfortable and possibly lighter than PDAs. Fifth, we will investigate and evaluate different game-style approaches to enhance motivation support of our mobile guide. Finally, we will consider mobile information visualization aspects [8] to design graphical presentations of users' performance data.

7. ACKNOWLEDGEMENTS

Enrico Di Lenarda helped us with 3D modeling aspects. Our research has been partially supported by the Italian Ministry of Education, University and Research (MIUR) under the PRIN 2005 project “Adaptive, Context-aware, Multimedia Guides on Mobile Devices”.

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