Mobile application to stimulate physical activity in schoolchildren

Božidara Cvetković, Vito Janko, Anton Gradišek, Mitja Luštrek
Department of Intelligent systems
Jožef Stefan Institute,
Ljubljana, Slovenia
{boza.cvetkovic, vito.janko, anton.gradisek, mitja.lustrek}@ijs.si

Tanja Kajtna, Boro Štrumbelj
Faculty of Sport
University of Ljubljana
Ljubljana, Slovenia
{tanja.kajtna, boro.strumbelj}@fsp.uni-lj.si

Abstract—**We present the "e-Gibalec" system, which was designed to stimulate and motivate schoolchildren to be physically active and to assist physical education (PE) teachers and parents to track their progress. The system consists of a smartphone application which uses built-in sensors to monitor activities, and a web application for PE teachers and parents. We present an overview of the system and its functionality. We also provide an initial evaluation of the accuracy of the monitoring obtained on 10 schoolchildren, and their subjective evaluation of the mobile application, which is quite positive.**

Keywords—physical education, activity recognition, energy expenditure, mobile application

I. Introduction

Physical education (PE) is an important part of school curriculum. Its objective is to teach children basic sport activities, and to instill the value of physical activity being an important part of their lives from childhood to old age. Physical activity contributes to health and personal well-being, and at the same time helps to neutralize the effects of the increasingly sedentary lifestyle and other bad habits.

Physical development and performance of elementary and high school students has been monitored in Slovenia for over 20 years using standardized tests [1]. These tests revealed a worrisome trend: the turn of the millennium marked a sharp increase in child obesity. Although the number of children with reduced or insufficient fitness has stabilized in recent years, the overall situation is considered bad nevertheless – the number is still over twice as high as it was 20 years ago.

The lifestyle changes can be related to an increased use of computers and other consumer electronics, but at the same time these technologies can be used as an educational tool to stimulate children to increase physical activity. Several studies [2] have already demonstrated that mobile applications can motivate children to be more active. A review of studies [3] also demonstrated that the best interventions with the aim of increasing physical activity in children are done through schools.

Several types of sport-related applications have been developed in past years. A large majority of these applications can be classified as "fitness trackers", consisting of a wearable device, such as a wristband, and a smartphone application. Examples of such products are Jawbone UP [4], Microsoft Band [5], and Fitbit [6]. However, these products are mostly aimed at adults and require a specialized device (the wristband). Some products have been designed specifically for children, such as Leap Band [7] and KidFit [8], which also use wristbands, or ibitz [9], which uses a belt- or shoe-mounted pedometer. These applications stimulate children to be active by awarding them virtual currency or allowing them to unlock higher levels in the game. However, we found no wide-scale use of such applications on school population and there are no such applications available in the Slovenian language. In addition, all above-mentioned applications use an external device which needs to be purchased, which makes them inaccessible for some. Smartphones on the other hand are owned by a majority of users including schoolchildren.

Here, we present the e-Gibalec system ("e-mover" in Slovene) [10] composed of a smartphone application designed for children (aged 10-13), and a web application designed for PE teachers and parents. It was developed with the aim to stimulate physical activity in elementary school children and to assist PE teachers in the teaching process. The smartphone application uses the built-in sensors in combination with intelligent algorithms to monitor physical activity and estimate energy expenditure of children. It employs gamification to motivate children to be more active. In addition, the application allows children to input their activities performed while not carrying their smartphone. The web application allows PE teachers to input the activities and their intensity during PE in school, and to monitor their students' activities in their free time.

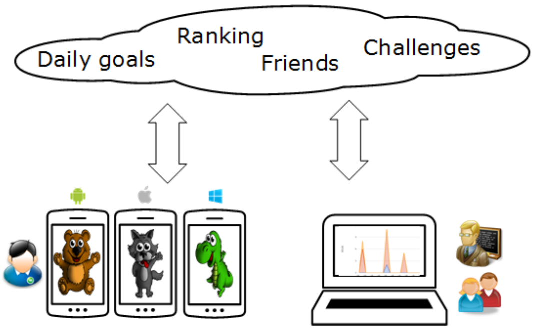

Fig. 1. e-Gibalec architecture. The smartphone applications are designed for schoolchildren and the web application for parents and PE teachers.

In this paper, we present an overview of the system and the results of the initial tests. Further tests are in progress to evaluate to what level the system motivates and increases physical activities of children.

II. SYSTEM DESCRIPTION

A. System architecture

The e-Gibalec system consists of a mobile application for schoolchildren and a web application for PE teachers and parents. Both applications are connected to a cloud, hosted by The Academic and Research Network of Slovenia (ARNES) [11] which is the internet provider for educational institutions in Slovenia. A brief system architecture is presented in Fig 1.

The mobile application was developed for all major platforms, the Android, iOS, and Windows Phone. It utilizes the data from the smartphone inertial sensor to monitor user activity and its intensity. The web application was developed using the Django platform and other open-source technologies. The e-Gibalec system has been made open-source and is available on Sourceforge [12].

B. Smartphone application

1) Functionality

The smartphone application was designed in collaboration with a sports physiologist with the aim to give the most relevant and simple information to the child. The child is required to register in order to track his/her progress in terms of activity and also in terms of achievements, awards and preferences.

When the child first logs into the application, he/she is assigned a default avatar in the shape of an animal, which guides and motivates the child with encouraging messages throughout the application. The initial screen shows the status bar indicating the progress towards the daily activity goal. The avatar shows different emotions according to the satisfaction with the achieved goal, as presented in Fig. 2.

When the child carries the smartphone (anywhere on the body), the application monitors the type and the intensity of the physical activity with machine-learning models for activity recognition and the estimation of energy expenditure from acceleration data [13]. In case the smartphone is not carried while the child is active (group sports, sports training, etc.) he/she can enter the activities manually, with parent or PE

Fig. 2. The initial screen of the e-Gibalec mobile application with the avatar and the status bar showing the progress towards the daily activity goal (left). Avatar in different emotional states, reflecting the the current state of the daily goal fullfilment (right).

teacher confirming their correctness using the confirmation interface of the web application. The monitored and manually entered activities are transformed into virtual coins. The amount of coins reflects the intensity of the active time. The coins can be used for in-application purchases of sports equipment as shown in Fig. 4 (left). Once the daily goal is achieved, the child is rewarded with a unit of special currency, depending on the currently chosen avatar (e.g., dinosaur – bone, fox – feather, wolf – ham, etc.). These can be used for equipment upgrades (bronze, silver and gold). At any time, the child can check how well he/she is doing on daily, weekly, or monthly scale (Fig. 3).

Fig. 3. Activity history for an individual day (left) and last week (right): graph shows activity intensity for each hour while pie chart shows types of activities (from top to bottom): resting, walking, running, individual sport, team sport, other.

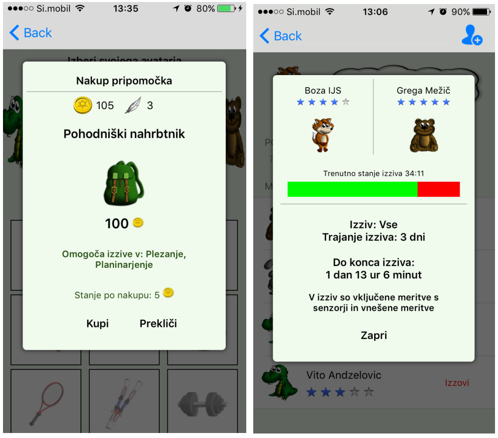

Fig. 4. Purchasing a backpack which enables challenge in hiking and climbing (left). The ongoing challenge between two friends (right).

An important aspect of the application is its social component. With sport equipment, the child can invite friends to specific or general activity challenges. For example, a racket can be used for challenges in tennis, table tennis, and badminton; a ball can be used for challenges in team sports such as football and basketball. The winner of a challenge is the person who is, in total, more active in the challenged activity during the challenge, which can span one to seven days. An ongoing challenge is presented in Fig. 4 (right). The winner of the challenge receives virtual coins. Upgraded equipment increases the reward.

In addition to challenges from other users, the application also contains a virtual challenger Veselko Gibalec ("Merry Mover" in Slovene) who occasionally invites to challenges of its own.

2) Activity monitoring methods

Activity monitoring is composed of two modules, the activity recognition (AR) and the estimation of the energy expenditure (EEE), where AR is a classification task and EEE is a regression task. They are both essentially done in the same way.

The stream of acceleration data is split into five-second windows for AR and fifteen-second windows for EEE. Then, a number of features are computed for each window, forming a feature vector. The feature vector is fed into a machine-learning algorithm, which outputs an activity for the AR and the expended energy in MET (Metabolic Equivalent of Task – 1 MET is energy expended at rest) for EEE. For more details, the reader is referred to [13].

C. Web application

The web application is designed for parents and PE teachers. Parents can confirm activities that children input manually, and also monitor their children's activities on a daily, weekly, or monthly basis. PE teachers can monitor activities of the whole class, which helps them to adjust PE classes, provide individual counselling to students and remotely set their daily activity goals in the e-Gibalec application.

III. Experimental Evaluation

To develop and evaluate the performance of the activity monitoring models for children, we collected a dataset of ten children, aged 10-12, equipped with the following devices: (i) three smartphones (trousers pocket, jacket pocket and bag), (ii) inertial sensors Chipolo [14] modified to stream acceleration data (wrist, trousers pocket, and a shoe), (iii) Empatica wristband [15] with accelerometer, blood volume pulse, heart-rate, galvanic skin response, temperature, and inter-beat interval, (iv) SenseWear armband [16], which estimates the energy expenditure and was intended for comparison with our methods, and (v) Cosmed [17], an indirect calorimeter device that measures the exhaled CO_2 which directly correlates with the energy expenditure.

Each child performed a series of activities from a pre-defined scenario, which included lying, sitting, slow and fast walking, slow and fast running, stationary exercise such as jumping and push-ups, team sports (dodgeball, basketball, football, volleyball), and cycling. Between the activities, children were allowed to take a break which allowed the energy expenditure to return to the resting level. The combined scenario took about an hour, which is approximately 5500 instances for AR and 2000 instances for EEE.

Since the goal of the project is to use only smartphone for the activity monitoring, we only report the results obtained this way.

The smartphone inertial data were collected with 50 Hz rate, but due to economic use of the smartphone battery we down-sampled the frequency to 10 Hz, which is used in the "light-weight" method in the e-Gibalec application. For the same purpose, we had to find the tradeoff between the number activities to recognize and number of features to be calculated for the classification and regression task.

We started with the recognition of six activities and approximately 60 features. The analysis of the most frequent activities in during which the children can carry the smartphone decreased this set of activities to four: rest, walking, running and cycling. The evaluation of the feature set with feature selection returned the optimal set of features to efficiently recognize the selected set of activities (five features). The used features are: average of magnitudes, the value of the third quartile, variance, coefficient of variation, and number of peaks.

The same approach was used for the optimization of the number of features for the EEE, where one of the features was the recognized activity. After the feature selection, we ended up with nine features in addition to the recognized activity: the magnitude skewness, kurtosis, variance, coefficient of variance, second magnitude quartile, inter quartile range magnitude, mean crossing rate, area under acceleration, and number of peaks in the window.

We compared the e-Gibalec "light-weight" method to the "complex" method from [13], which is intended for adults and has a wider range of activities that can be recognized. The evaluation and comparison was done on the dataset of children. The compared method has five steps: (i) it detects walking to retrieve the smartphone orientation, (ii) it normalizes the orientation (iii) it recognizes the location of the smartphone (trouser pocket, breast pocket or bag), (iv) it recognizes the activity with a model adapted to the recognized location of the phone, and (v) it finally estimates the energy expenditure. The results are presented in Table I in terms of the accuracy of the AR and the mean absolute error (MAE) of the EEE.

TABLE I. THE RESULTS OF THE E-GIBALEC LIGHT-WEIGHTED METHOD COMPARED TO THE COMPLEX METHOD [13].

Method and location of the smartphone	*AR [%]*	*EEE [MAE]*
e-Gibalec[a] – all locations	95	1.10
Complex method[b] – trousers pocket	63	0.95
Complex method[c] – jacket pocket	75	0.72
Complex method[d] - bag	91	0.72
SenseWear device[e]	/	1.40

a. Recognizes rest, walking, running, cycling
b. Recognizes lying, sitting, standing, walking, running, cycling
c. Recognizes upright, lying, walking, running, cycling
d. Recognizes rest, walking, running, cycling
e. *Commercial device*

The goal of this comparison was to evaluate whether we the gain in accuracy in terms of AR and EEE by introducing the "complex" method is worthwhile. We can observe that the AR accuracy is the highest when e-Gibalec "light-weight" method is used. This is because the "complex" method was trained on adults and the height of the person plays an important role when it comes to AR, since the movement magnitude and the angles of movement are downscaled in children. Interestingly, when observing the EEE error, we can see that the location and orientation of the smartphone improve the estimation significantly even if we use the models trained on adults. This indicates that training models on children for separate locations might decrease the error even more. We nevertheless decided to use the "light-weight" method, since it is computationally less expensive and thus preserves the battery life, and is less likely to behave unexpectedly in real life due to its simplicity.

The methods were also compared to the commercial SenseWear armband, which was found to be the most accurate one (for adults) among off-the-shelf devices [16]. It appears that this device is not well-suited for children, since its error was larger compared to our previous work on adults, where SenseWear MAE was always around 1 MET.

We also tested the subjective perception of the e-Gibalec mobile application by the children. After using the application for two around weeks, they were asked to rate it on a five-point scale in four categories. The results of this evaluation are shown in Table II and indicate the children were quite satisfied.

TABLE II. THE RESULTS OF SUBJECTIVE EVALUATION BY CHILDREN.

Category	*Average score*
Overall	4.1
Attractiveness of avatars	4.4
Usefulness of challenges	3.9
Motivation for sports	4.0

IV. CONCLUSION

We presented an application that stimulates children to be physically active. It employs built-in smartphone sensors to monitor activity and uses a gamification approach to motivate the user. The application also helps PE teachers and parents to monitor children's activities. In contrast with other fitness trackers, aimed at children, e-Gibalec relies solely on a smartphone and does not require an additional wearable device.

Activity recognition and energy expenditure estimate models were trained on a dataset recorded on 10 children. To evaluate the performance of the models used in the e-Gibalec application, the AR and EEE predictions were compared to those of a more complex method and those provided by a commercial device. AR turned out to be better than in other approaches, while the EEE was somewhat worse than with the more complex model, but still better than with the commercial device.

Future work includes running a controlled experiment on schoolchildren to determine to what degree the use of the application increases their physical activity. In addition, we plan to train and evaluate a complex model using the children dataset. We will evaluate individual and combined sensors collected in the children dataset for the activity monitoring task.

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