On11: An Activity Recommendation Application to Mitigate Sedentary Lifestyle

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ABSTRACT
Sedentary lifestyles have become ubiquitous in modern societies. Sitting, watching television and using the computer are sedentary behaviors that are now common worldwide. Research studies have shown that how often and how long a person is sedentary is linked with an increased risk of obesity, diabetes, cardiovascular disease, and all-cause mortality. Effective strategies for motivating people to become more active are now crucial. In this paper, we present a smartphone application called "On11", which runs in the background of users' smartphones and monitors their daily physical activity continuously. Unlike traditional pedometers that only passively count steps and estimate burnt calories, On11 also detects sedentary behaviors (sitting, lying down). It presents "at-a-glance" summaries of what percentage of the user's day have been spent sitting, walking, and running, and total calories burnt thus far that day so that the user can self-reflect. It records the intensity, duration, and type of activities performed and recommends personalized short walks and detours to users' regular routes such as home to workplace. The user can set performance goals, which allows On11 to suggest activities to help them meet their goals. The results of our preliminary user study were encouraging.

Categories and Subject Descriptors
H.4.m [**Information Systems Applications**]: Miscellaneous—smartphone application

General Terms
Design, Experimentation, Measurement, Human Factors

Keywords
Sedentary lifestyle, smartphone application, activity recommendation

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1. INTRODUCTION
A sedentary lifestyle is one in which people engage in very little physical activity or exercise, leading to obesity. The activities performed by sedentary individuals daily do not increase their energy expenditure substantially above resting levels. Activities such as sitting, lying down, sleeping, watching television, playing video games, and using the computer—are typical examples. Wilmot *et al.*'s recent review on previous sedentary lifestyle studies shows that sedentary time is linked with an increased risk of diabetes, cardiovascular disease, and all-cause mortality. Specifically, higher levels of sedentary behavior are associated with a 112% increase in the Relative Risk (RR) of diabetes, 147% increase in cardiovascular disease, 90% increase in cardiovascular mortality, and 49% increase in all-cause mortality [19].

The Centers for Disease Control and Prevention (CDC) recommends that adults should (1) perform at least 150 minutes a week of moderate-intensity, or 75 minutes a week of vigorous-intensity aerobic physical activity (2) Aerobic activity should be performed in episodes of at least 10 minutes, and preferably, it should be spread throughout the week [18]. However, CDC data [7], has found that less than half (48%) of all adults perform this recommended amount of physical activity in the United States, and the direct medical cost of insufficient physical activity is approximately 24 billion dollars [5].

The low participation rate in physical activities has many causes. Toscos *et al.* found 17 recurring reasons including lack of time, lack of motivation, injury and physical exertion [16]. Many people have careers that require long periods of sitting and typically plan a few hours a week dedicated to intense exercise such as running, playing tennis, or going to the gym. However, attrition rates are usually high partly because many people are too ambitious in attempts to exercise after many months or years of being sedentary. In prior work, we have found that up to a third of runners quit after just one attempt at running [7]. In this work, instead of promoting intense bursts of exercise for a few hours a week, we encourage people to walk more during their day by adding interesting "detours" into their usual routes, e.g. visit a flower shop while walking home from their office and mini-walks during their day at the office. Moreover, Wilmot *et al.*

recently concluded that a few hours of intense exercise cannot mitigate the effects of long hours of sitting [19].

We developed a smartphone application called "On11" that continuously monitors total calories burnt and what percentage of the user's day have been spent sitting, walking, jogging and other activities, which it presents to the user in an "at-a-glance" summary for self-reflection. Unlike traditional pedometer that passively counts steps and estimates burnt calories, On11 suggests personally tailored walking recommendations based on the users' context (location, time, weather). The user can set performance goals, which allows On11 to suggest appropriate activities to help them meet their goals. Our preliminary user studies are encouraging. Prior work has focused mostly on tracking user activity but do not generate context-aware activity suggestions that are tailored to achieve goals set by the user and in response to detected sedentary behaviors.

The remainder of this paper is as follows. Section 2 discusses related work. Section 3 describes the specific user context information used in On11. Section 4 and 5 describe the design and implementation details of our app "On11", respectively. Section 6 presents our preliminary evaluation of On11's functionality followed by the concluding remarks presented in Section 7.

2. RELATED WORK

"Physical activity" is defined as any bodily movement produced by skeletal muscles that results in energy expenditure, but which can be distinguished from "exercise" [4]. From the perspective of intensity, the spectrum of physical activity can be divided into 4 categories: Sedentary Activity (1.0-1.5 METs), Light-intensity Physical Activity (LPA, 1.6-2.9 METs), and Moderate-to-Vigorous-intensity Physical Activity (MVPA, ≥ 3.0 METs). Ainsworth *et al.* present a compendium of physical activities which includes over 100 detailed sedentary activities [1]. Page *et al*. define "sedentary activities" as activities such as sitting, lying down or watching TV in which energy is expended at 1.0-1.5 METs, which is not substantially above the resting level [15].

Self-monitoring is a key step in behavior change. Bravata *et al.* [3] found that the use of the "pedometer" for tracking distances walked led to significant increases in physical activity as well as significant decreases in body mass index (BMI) and blood pressure. Early pedometers used a mechanical switch to detect steps and a counter to log steps. Today, a new generation of pedometers is made with one-, two-, or three-axis Micro-Electro-Mechanical Systems (MEMS) accelerometers and run sophisticated software algorithms to detect steps. Accelerometer-based pedometers are more accurate, more programmable, more wearable in terms of size and are commonly used in activity measurement studies [17].

Today, various types of commercial body-worn physical activity trackers are now available from companies such as Nike, Fitbit, Jawbone, Withings, and BodyMedia. These devices can measure the distance walked by users, the number of stairs or building floors climbed, calories burnt, weight changes, and blood pressure fluctuations. Some of these devices can also synchronize users' measurements with applications on their smartphones or upload the data to their personal health records in the cloud.

UbiFit Garden [6] was one of the earliest approaches that uses a mobile phone for tracking and encouraging physical activity. In this system, Consolvo *et al.* used a sensing device to infer a user's physical activities, which were presented to the user on a cellphone GUI. Today, many widely owned smartphones have built-in sensors such as triaxial accelerometers, gyroscopes and GPS. Smartphone applications can be programmed to utilize these sensors to continuously monitor the user's movements, turning smartphones into continuous activity trackers. Apps such as AndWellness [9], BeWell [11], and ohmage [14] utilize such sensor-equipped smartphones. Recently, commercial activity tracking apps such as Moves, Nike+ Move, ARGUS, Accupedo Pedometer, Noom Walk, and Runtastic Pedometer have also become popular on smartphones. However, these apps mostly track and quantify human activity such as the number of steps walked and calories burnt but do not give personalized suggestions based on the user's behavior patterns and context. While a few of them allow the user to set performance goals, they only present the user's progress towards set goals but do not provide further suggestions when goals are not met.

Our goal in creating On11 was to develop a smartphone application that classifies and quantifies various types of physical activity performed by users throughout their day. "At a glance" summaries of the percentage of a user's day spent sitting, walking, jogging, and various activities are presented to the user for self-reflection. Based on a user's context (location, time, weather and personal preferences), convenient walking suggestions and detours are then suggested to encourage more physical activity. The user can set performance goals, which allows On11 to suggest activities to help them meet their activity goals.

3. CONTEXT AWARENESS

Context is any information that can be combined to determine the situation of a user. Since the definition of context varies in different scenarios, we now define the context we use in On11.

Time. Users are more likely to perform physical activities or walks suggested at the most appropriate times. In our previous study [8], we discovered that people were more likely to run in the mornings and evenings on

weekdays and in the daytime on weekends. On11 factors in time when suggesting activities.

Location. Toscos *et al.* found that "lack of resources" and "lack of the right equipment" are among the many barriers preventing people from participating in physical activities [16]. Nearer exercise locations are more convenient for people to go to, making them more likely to accept suggestions of physical activity. On11 finds the closest gyms and fitness clubs and suggests activities based on the user's preference. If no nearby gym or fitness club exists, On11 finds nearby fields that can be used as places for walking (LPA) or jogging (MVPA).

Weather. The current weather at a user's location should be factored in to determine whether an indoor or outdoor activity should be suggested. Outdoor activity suggestions are inappropriate if the weather forecast at a user's location predicts a high chance of precipitation. Other weather conditions such as high/low temperature and poor air quality should also be considered when generating physical activity suggestions.

Personal Information. Personal information such as the user's schedule and current fitness level can also be used to tailor recommendations. By looking up a user's electronic calendar such as Google Calendar, a smartphone app can determine the best times to popup activity recommendations. Other personal information such as weight can be used to calculate burnt calories, and also to decide whether a specific physical activity should be recommended. For example, running may not be a good idea for elderly or overweight users because their knees and calves may not be able to endure the impact of such intense physical activity. Other factors such as height, BMI, waist, gender, and medical history should also be considered.

4. ON11 APPLICATION DESIGN

On11 consists of three main modules: activity logger, inactivity detector, and recommendation generator. Additionally, a battery management module for optimizing battery life and modules for profile and goal setting are integrated. The On11 architecture is shown in Figure 1.

4.1 Function Design

On11 recognizes physical activities such as walking, running and sitting, which are performed by smartphone users. The activity classifier analyzes the smartphone's accelerometer values continuously while the user is carrying his/her phone during their day. The activity logger then logs the user's activities. Extended periods of user inactivity, sitting or sedentary patterns trigger the inactivity detector, which causes On11's recommendation generator to attempt to generate personalized activity recommendations. While On11 tracks and presents statistics on a wide range of the user's physical activities, its recommended activities are currently limited to walking. This is because the intensity of walking is relatively low, and can be performed by most users. Recommended activities encourage users to walk more by (1) adding detours into their usual travel routes such as home-workplace route or routes to their frequently visited destinations; and (2) suggesting mini-walks around their work place such as walking to the coffee lounge.

The act of setting a goal may be a key motivational factor for increasing physical activity, irrespective of whether the goal is aggressive or conservative [3]. In On11, users may set three types of goals: Keep Healthy, Lose Weight, or Burn Calories. Since some On11's functions such as data logging run continuously in the background, the smartphone's battery life is an issue. In On11, a battery manager cooperates with the activity logger module to adapt its sampling rate in order to optimize battery life.

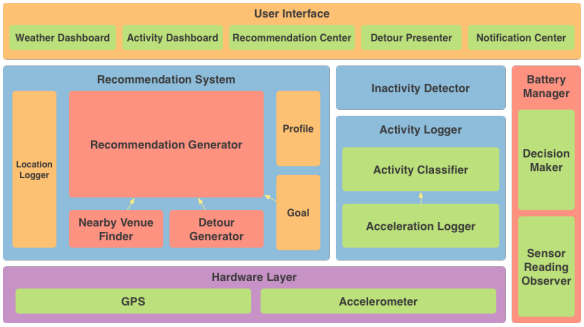


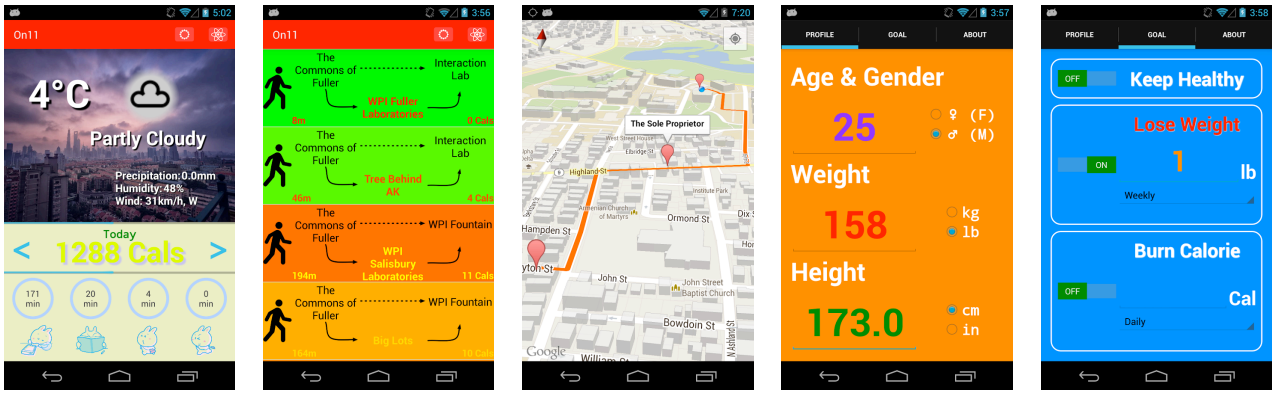
Figure 1. Architecture of On11

4.2 User Interface Design

An engaging User Interface (UI) is important because engaged users are more likely to be motivated to be active. On11 has five distinct UIs: main, recommendation, detour map, profile, and goal, which are shown in Figure 2.

Main UI: The Main UI provides weather information and a summary of how active the user has been (Figure 2a). The screen has two parts—a weather board and an activity dashboard. The main UI is the first screen users see after launching the app. The upper half of the main screen is the weather dashboard, which shows the latest weather information at the user's current location with a nice background photo selected from National Geographic's "Photo of the Day: Nature & Weather" channel. The lower half of the main screen is the activity dashboard, displaying a summary of the user's physical activities for the day: (1) how many total calories have been burnt thus far that day (as estimated by On11); (2) how much progress the user has made towards their personal goal (the blue progress bar under calorie number); (3) how many minutes the user has spent performing sedentary, sitting, walking, and running activities. Users can view their history data by clicking the navigation buttons ("<" and ">") on the left and right.

Recommendations UI: Recommendations generated by On11, which are sorted by the likelihood that users will accept them, are shown in the Recommendation UI (Figure 2b). For each recommended activity, the user's current location is shown on the left side, the recommended detour



(a) Main UI **(b) Recommendation** **(c) Detour Map** **(d) Profile** **(e) Goal**

Figure 2. On11 User Interfaces

is in the middle, the suggested walking destination is on the right side, the total distance is at the bottom left, and the estimated calories required is at the bottom right. The color of each recommendation indicates how intense the recommended walking activity is. An orange color means "hard" in terms of the amount of calories that will be expended, and a green color means "easy".

Detour Map UI: When the user clicks on a recommended activity, a walking route for that recommendation will be rendered on a 3D map (Figure 2c). The origin, destination, and detour will be shown on the map along with the route.

Profile UI: In the Profile UI (Figure 2d), users can input their gender, age, height, and weight in order to get accurate estimates of the calories they burn performing various activities. Users may also choose their preferred units for measurements.

Goal UI: In the goal UI (Figure 2e), the On11 user may select one of the three types of goals supported: Keep Healthy, Lose Weight, and Burn Calorie.

5. IMPLEMENTATION

We implemented On11 on Android OS 4.0+ (API 14+). The smartphone we used for development and testing was Google's Nexus 4 smartphone. In addition to APIs available in the Android API, other software libraries used include foursquare-api-java 1.0.3, JDOM 2.0.4, ORMLite 4.45, and Weka 3.6.6.

5.1 Activity Logging

On11 can recognize "Sitting", "Walking", "Running" or "Phone on Table[1]" activities by the smartphone user. To implement activity recognition, we adapted algorithms described in prior work [2, 10]. We collected 2,330 samples at a sampling interval of 4 seconds with physical activity type labeled. Then, we extracted four features from acceleration: and computed the averages and standard deviations of acceleration projections to the horizontal axis and vertical axes. We utilized Weka for training an activity classifier. Kwapisz *et al.* [10] have shown that decision trees (J48), logistic regression, and multilayer neural networks can achieve high levels of accuracy on smartphones with a single accelerometer. For the two most common activities, walking and running, over 90% accuracy was achieved. While there are other more sophisticated activity recognition algorithms that use supervised or semi-supervised machine learning techniques to achieve higher accuracy, considering computational complexity and ease of implementation, we decided to use J48 in our On11 app.

5.2 Inactivity Detector

If a user is inactive[2] for more than 90% of the last 30 minutes, or 27 minutes, On11 will notify the user by flashing the notification LED on the phone, playing a notification sound or vibrating. It then recommends that the user should stand up and take a walk (Figure 3).

5.3 Recommendation System

Motivating people to be more active is a complex and difficult task. Good suggestions should not only "make sense" to the user, but also be at intensity levels that are "appropriate" for the user.

Location History: On11 tracks a user's movement history and uses it to establish the user's preferred routes. When possible, walking recommendations follow the routes, which previously occurred in the user's location history. Once On11 collects enough location history, it can figure out the user's habits such as "when the user usually goes for lunch" and "when the user will go home". Detour recommendations can be given to extend such planned walks. On11 uses the smartphone's GPS, Cell-ID, and Wi-Fi to detect the user's location. Only locations at which the user has stayed for more than a fixed length of time are considered as visited locations.

[1] Technically, "Phone on Table" is not a physical activity. We assume users only put their phones when they are inactive.

[2] We consider "Sitting" and "Phone on Table" as "inactive".

***Nearby Places**:* Using Foursquare's API, On11 can find interesting nearby locations (known as "venues" in Foursquare) for a given location. These venues will be used in On11 as waypoints for generating detours.

***Detours**:* On11 predicts the user's next possible locations from their location history. When a user asks for a recommendation, it will generate several walking routes from the user's current location to these predicted "next locations". Since the goal is to encourage users to be more active, a detour waypoint will be added into the route. For instance, if a user usually walks from her/his home to office, then, On11 may recommend that the user should walk first from their home to a coffee shop, which is located near the midpoint of her/his daily route, and then, walking from this coffee shop to the office. If On11 cannot find any possible "next location", it uses the current location as both the origin and destination for a route. Venues near the user's current location are used as detour waypoints. In other words, On11 will generate a round trip from the current location to a venue.

Finally, walking routes are generated using Google's Directions API to guide the user walk from the current location to the destination via a detour waypoint. More details of the algorithm flow are described in Figure 4.

6. PRELIMINARY EVALUATION

To evaluate the functionality and the user experience of On11, we conducted a user study by recruiting participants from the Social Science Participant Pool of Worcester Polytechnic Institute (WPI). Psychology students in this pool get academic credit for participating in user studies. This study was IRB approved. The study started on November 8, 2013 and ended on November 22, 2013. Seven subjects were recruited from the pool, and two participants from the Interaction Lab of the Department of Computer Science at WPI also volunteered. One subject dropped out of this study because she/he was not interested in our study and didn't care about the research credits (as compensation) any longer.

The user study consisted of three parts: performing tasks in a User Guide Tutorial, an App Trial, and a Post-survey. In the User Guide Tutorial session, we helped the participants install our On11 app and setup their Android phone properly. After the tutorial, participants used On11 for 2 weeks, during which we provided technical support online through Google+ Communities and email. After the trial, we then asked the participants to answer a questionnaire regarding to their On11 experience and any changes in their sedentary levels.

Since the number of subjects was not large enough to make statistically significant conclusions, our findings are mostly qualitative. We shall now discuss common points on which the participants agreed on as well as present their comments. Five of eight participants reported that activity recognition worked accurately and inactivity was detected correctly when their phones were attached to their body movements. However, the acceleration reading from one participant's phone was not accurate. The manufacturer of that phone may not have calibrated the accelerometer properly. We found long periods of "Phone on Table" in our participants' daily life [Figure 5], which implies that while a smartphone enables global scale dissemination, it may not be the best device for 24/7 activity tracking. Wearable devices such smartwatches might be a better solution.

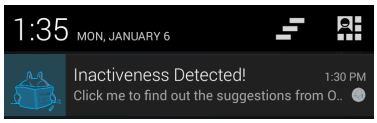


Figure 3. On11's Notification Shown in Android OS

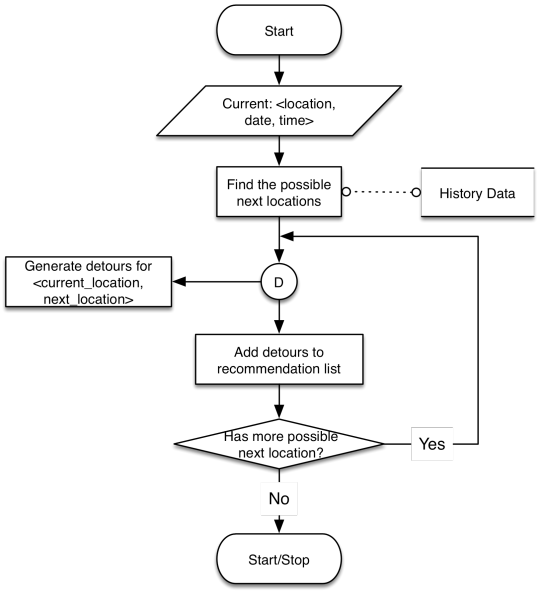


Figure 4. Flowchart of Generating Detours for <origin, destination> Pair

Six subjects liked the way "at-a-glance" presentation of activity time. One subject mentioned in the post-survey, "*Very cute and definitely the aspect I utilized the most when using the app. It was a good comparison at seeing how sedentary or active I am in a given day.*" Also, the overall UI was preferred, "*Design of the app was organized and fairly straightforward*", and "*Background added positively to the visual appeal.*"

Participants commonly didn't want to be bothered by telling them "they were inactive" too frequently even if they knew it was true, which suggested that we should investigate better ways to inform users of their sedentary patterns without annoying them in future iterations. With regards to the recommendations generated by On11, one subject wanted rewards for accepting our detour recommendation. Another subject said she/he would follow the recommendation only if it wouldn't make life much

harder. In the future, we will track which suggested detours are accepted by users and store such usage data for research use. This will enable us understand the efficacy of this intervention. Finally, we found that battery life was a significant concern while using our On11 app.

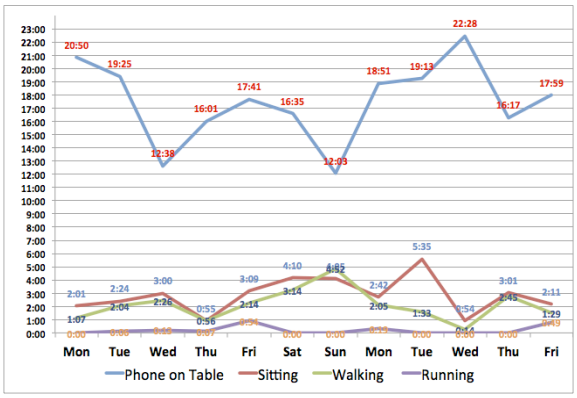


Figure 5. Average Activity Time

7. Conclusion

In this paper, we described the design, implementation, and evaluation of On11, a futuristic activity tracking application for smartphones. On11 continuously monitors users' physical activity, detects sedentary patterns, learns users' geographical patterns, and provides personalized walking recommendations based on time and location. On11 makes people more aware of their unhealthy behaviors by highlighting sedentary behaviors. It also encourages people to be more physically active by adding detours into users' regular routes and suggesting mini-walks during their day. Our prototype On11 implementation demonstrates the viability of activity recommendation based on detected user behaviors using off-the-shelf smartphones.

In the future, we plan to add more sensing and intelligence to On11. For instance, On11 can learn user's schedule by scanning her/his calendar in order to suggest optimal activity times. On11 may sense the user's well-being by analyzing her/his social interactions (e.g. number of phone calls, SMS, emails) [12] to detect changes in communication patterns that may indicate illness. Various location types and routes may be inferred automatically by analyzing audio recordings of "sounds of the environment" that are opportunistically gathered [13] in order to improve suggested routes. We will also consider adding comparisons with other users (socio-norming) into the app and provide more diverse activity recommendations other than walking, e.g. "7-Minute Workout". A large-scale user study will be conducted in the next iteration of On11 development to better understand sedentary patterns shown by different users and effect community-level interventions and change unhealthy behaviors.

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