

# Automated Mobile User Experience Measurement: Combining Movement Tracking with App Usage Logging

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## ABSTRACT

We present a new suite of tools for automated measurement of user-system interaction on mobile devices. The system combines measurements of the usage of mobile apps, with a visual representation of the user's location and behavior. This makes it possible to assess not only what the user is doing on the smartphone or tablet, but also what he or she is doing in various different outdoor or indoor locations. The tool offers fully automated data collection and has been designed for deployment in user experience studies with multiple participants for extended periods of time.

## Author Keywords

HCI, Android, Mobile, Tracking, User Interaction

## ACM Classification Keywords

Tracking, HCI, User Interfaces, Evaluation/methodology, User Interfaces, User-centered design.

## INTRODUCTION

The exponential growth of sales of smartphones and tablet computers has been followed by an equally rapid proliferation of software applications ('apps') to run on those devices. However, tools for developers of mobile apps have not evolved at the same pace. One example are tools for measuring the user experience, in particular the interaction of the user with a tablet or smart phone.

User experience and usability of mobile apps can be evaluated in a laboratory setting, by observing a user while operating the device, followed by video annotation and analysis of user-system interaction [1]. However, lab studies of mobile devices are limited in terms of ecological validity, which restricts the scope of conclusions and recommendations. User interaction with mobile devices can also be captured in the field, by recording the interaction using a mobile device camera [2, 3, 4, 5] attached to the tablet or smartphone, with the screen movie (including audio) being stored on a portable hard drive, followed by

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video annotation and analysis in the lab. Although user interaction can be recorded in great detail, the recording hardware does not permit entirely natural operation of a mobile device, rendering this method unsuitable for observations of long duration. Furthermore, the equipment cost and time needed for data collection prohibit large-scale deployment. An alternative for a mobile device camera is video recording of user-system interaction by a person following the user, as has been proposed for studies in mass transit settings [6] and sport stadiums [7]. However, although this gives the user more freedom to behave naturally, it sacrifices observational detail and is even more labor-intensive than the use of a camera attached to the mobile device. The application of user-centered design methods in mobile app development calls for new tools, offering fully automated user experience evaluation in large numbers of participants.

Several authors have proposed automated data collection methods for remote usability testing on mobile devices. Waterson et al. [8] used proxy-based clickstream logging to capture user traces of a given task without having to modify the participant's software or to access the server. They concluded that this technique allowed them to find usability issues related to the web content displayed on mobile devices. Jensen and Larsen [9] logged user actions on a mobile device in longitudinal studies lasting three months, by instrumenting the app with specific hooks in the source code. This allowed a detailed analysis of the frequency, temporal and sequential structure of the usage of various program functions. However, none of these tools takes into account the user's location during operation of specific apps or functions.

To properly understand how a user makes use of various apps it is necessary not only to obtain data about which apps are in use at which moments, but also, given the mobile nature of the devices, the location of the user needs to be registered. Additional insight can be obtained if we know the movement status of the user: standing still, walking, in a car, bus or train, etc., because this has implications for the ergonomics of the app. If spatial and movement information is available, the interpretation of when, where and how someone is using a particular app has much more power. For example, the function of a public transport app can be assumed to vary according to whether a user is at home (planning a trip) or at a railway station (finding departure time and platform). In order to obtain this information, the designer of a mobile app needs a tool that tracks the location of the user, logs which app(s) are being used, and collects data about the user experience. Examples of questions that may arise are: Where do people use the new

shopping planner: at home, on the go or in the supermarket? Does the usage of the app in time and space differ between males and females? Does the duration of usage differ between different locations? Is my app used while the user is walking or only when he/she is stationary?

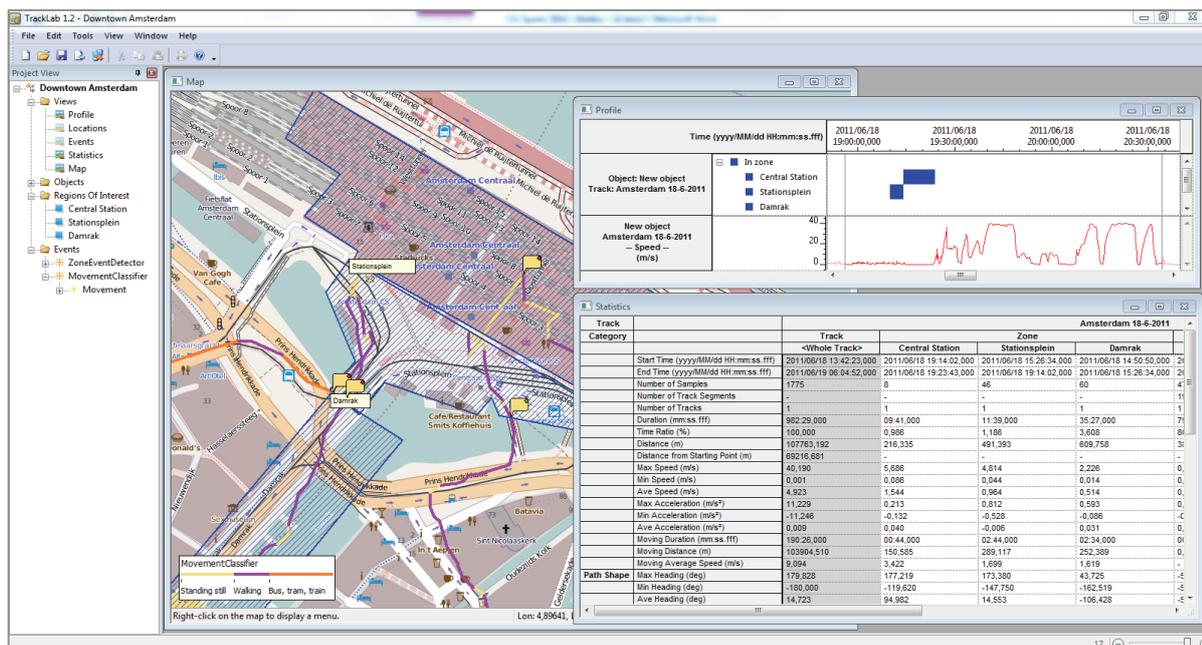
Noldus InnovationWorks, the research and innovation laboratory of Noldus Information Technology, has embarked on the development of a suite of tools that offer these functions in an automated and integrated manner, to support mobile HCI research and the development of apps for smartphones and tablets. Here we report on the first two components: integrated tracking, visualization and analysis of (a) user location and movement and (b) app usage.

## METHODS

The system being developed consists of a number of components: location tracking, movement analysis, app usage logging, data visualization and data analysis. These will be described below. Location tracking and app usage logging are implemented in a Java program named AppTrack™, which runs on smartphones and tablets with Android 2.0 and higher.

useful information. For instance it could enable categorization of the location as ‘at home’, ‘at work’, ‘commuting’ or ‘other’. We are also looking into other techniques for indoor positioning, based on video, ultra-wideband, WiFi or ZigBee sensing, to provide more detailed spatial information. The sampling rate (number of fixes per unit time) can be set by the researcher; it is a trade-off between data storage and analysis limitations (higher sampling rate → larger track file), desired spatial accuracy (higher sampling rate → more precise detection of zone entry and exit) and temporal resolution (higher sampling rate → more reliable movement classification), as determined by the research requirements. The default sampling rate is 1 Hz. The track file created on the mobile device consists of a log of fixes, each consisting of date, time, longitude, latitude and elevation in comma-separated values (CSV) format.

The location data collected on the mobile device are passed on, using a custom-design data transfer program using the SMB protocol, to TrackLab™, a PC-based Windows application for track visualization and analysis [9]. This tool was introduced as a research tool in 2013 and is being used for research in psychology, ambient assisted living [10] and consumer behavior [11]. The data are first cleaned up and



**Figure 1. Track of a single user, recorded by the GPS sensor in his mobile device, with color-coded movement categories. The inserts show a profile of zone transitions and movement variations over time, and a table with detailed movement statistics for the entire track and for each region of interest separately.**

## Location and movement tracking

The built-in sensors of the smartphone or tablet are used to detect and log the spatial position of the user. When the user is outside, or under a roof which does not block GNSS satellite signals, the built-in GPS sensor is used. If a GPS signal is not available, then we will investigate the most practical solution. The rough location data provided by the wireless telecom network will in many cases be sufficiently

filtered using the mechanisms built in to TrackLab, including outlier removal (based on a user-defined acceleration threshold) and smoothing. Especially with GPS data, this is a necessary step due to artifacts inherent in this type of data, especially if the subject is standing still, or if they are in a location with insufficient open sky, or surrounded by reflective surfaces (‘urban canyons’).

## Movement analysis and behavior classification

TrackLab allows movement tracks to be plotted on a map, which can either be an outdoor map, provided by an online map provider, or the floor plan of a building (e.g. an office, museum, hospital, railway station). For online maps, TrackLab currently supports OpenStreetMap but other map providers are considered too. Tracks can either be plotted as individual lines (i.e. one for each participant) or aggregated as 'heat maps', which provide a color-graded density plot. Figure 1 shows an example of a track visualization overlaid on a city map.

moment when a particular app gets or loses the focus. At a rate of 0.5 Hz, it generates a list of all active apps, #1 in the list being the app that has the focus. As soon as change in the #1 position occurs, this means that another app has received the focus. At that moment the start time, end time and name of the previous focal app are logged. Going into standby mode (or the screen being switched off) also causes an end time to be logged. The log files are written in CSV format. They are transferred to the PC and into TrackLab in a similar fashion as the track files.



Figure 2. Color-coded app usage overlaid on a movement track. Red = standby mode, light blue = App 1, dark green = App 2.

Based on the position data, TrackLab computes the user's speed of locomotion. This parameter can be visualized as a color gradient in the track or used to define different categories of movement (e.g. standing still, walking, motorized movement in bus, tram or train). The latter can be visualized as distinct track segments (Figure 1).

TrackLab has been designed to cope with large numbers of tracks, each containing large numbers of data points. The performance is mostly limited by available computing resources. With a sampling rate of 1 fix/second (usually sufficient for spatial event detection and movement classification), a data set can contain tracks of hundreds of participants being tracked for multiple hours.

### App usage logging

To record the usage of apps on the mobile devices, AppTrack keeps track of all active apps and records the

The app name in the log file, for one and the same application, can vary depending on the language settings and the smart phone brand. This is a point of attention in studies with multiple participants, if one intends to pool the data across participants.

### Data integration

Besides location data, the TrackLab program can also load event data such as the app usage log files, and couple those to the corresponding track file. This opens the way for a detailed analysis of the recorded data from the smartphone, the logging of the active application(s), together with the logged position data. The data can be visualized on an OpenStreetMap map (for outdoor data) or floor plan (for indoor data), such that easily can be seen which apps are used where. The usage of apps in a certain area of interest, a user defined zone, can be analyzed as well. Figure 2 shows a track of a user with color-coded app usage. This visualizes

in an intuitive manner how the user alternated between different apps, which app was used where and when, how long each app was used, etc. Detailed statistics can be computed for app usage in user-defined regions of interest (e.g. streets, parks or neighborhoods), time windows (morning, afternoon, evening), or combinations thereof.

## DISCUSSION

The rapid development of software for mobile devices requires that tools for measuring the users' interaction with those devices have a number of specific functions. This includes the possibility to measure the user interaction without a keyboard or mouse. Because the devices are mobile, their location and locomotion status of the user are also of critical importance for interpretation of the data. In order to include multiple test participants and collect data for a meaningful period of usage, data collection must be fully automated. The ongoing development presented here is intended as a step in the direction of a comprehensive measurement and analysis tools suite for HCI research on mobile devices and applications.

## Future developments

Besides the GPS receiver, smartphones and tablets contain many more sensors that allow the context of use to be recorded, including accelerometers, gyroscopes [12], camera and microphone. Furthermore, we wish to capture the user's intention and experience by providing real-time feedback functions. In the future, these data sources will be added to our tools suite to enhance the capabilities of automated UX evaluation.

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