TinyBlackBox: Recovering the Lost Interactions of Mobile In-the-Wild Studies

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ABSTRACT
Most work investigating mobile HCI is carried out within controlled laboratory settings; these spaces are not representative of the real-world environments for which the technology will predominantly be used. The result of which can produce a skewed or inaccurate understanding of interaction behaviors and users' abilities. While mobile in-the-wild studies provide more realistic representations of technology usage, there are additional challenges to conducting data collection outside of the lab. In this paper we discuss these challenges and present TinyBlackBox, a standalone data collection framework to support mobile in-the-wild studies with today's smartphone and tablet devices.

Categories and Subject Descriptors
H.5.2 [**User Interfaces**] Evaluation/Methodology, User- Centered Design; D.2.2 [**Design Tools and Techniques**]: Miscellaneous

Keywords
Mobile Computing, In-the-wild, User-Centered Design, Data Collection, Toolkit

1. INTRODUCTION
Mainstream success of smartphones and tablet devices has resulted in new forms of computer interactions - whereby the location and environment play a key role in the overall user experience. The mobile nature of these devices means that users are no longer confined to the traditional chair and desk setting, but are free to move around and interact on the go. This design space offers a vast number of opportunities for location-aware and context-specific interactions that were previously not possible. With more and more computer interactions shifting into the mobile design space, there is an urgency to understand what effect the environment has on the user experience and interaction effectiveness – thus, the need for user studies outside of the laboratory.

In recent years, there have been a growing number of HCI works that have explored in-the-wild or in-situ interactions with mobile technologies [1,3,5,6]. While these works report on the positive benefits from gathering real-world evidence and usage behaviors, they equally discuss the additional challenges and complexities that go with conducting HCI research outside the controlled laboratory environment, particularly capturing sufficient details and context to frame the device interaction. Having experienced these challenges firsthand in mobile accessibility research, we recognized the need for software solutions to better support the data gathering from mobile in-the-wild studies with today's smartphone technologies. To this end, we present TinyBlackBox (TBB), an open-source system-wide data collection solution for Android mobile devices. TBB is capable of capturing any and all sensor measurements from the device, low-level touchscreen interactions, and the corresponding application interface elements. Data is captured locally on the device, and using opportunistic synchronization with Google cloud services, it can be aggregated with data from all of the study participants. In addition to these collection mechanisms, TBB provides an API to extend the log files and capture study specific information. Finally, to aid the analysis of the log data, we developed an interactive playback tool. Allowing researchers to replay any user interactions within the context of the screen that they were recorded in (Figure 1).

In this paper, we discuss the trends and challenges of mobile in-the-wild studies, highlighting the strengths and weaknesses of the current approaches. Moreover, we describe TinyBlackBox, the proposed no-code solution to mobile in-the-wild evaluations.

2. MOBILE INTERACTIONS
Previous works have stressed the importance of studying technology use in the real-world, particularly when exploring accessibility challenges [1,5,6]. However, the research methods and data collection techniques can impose significant constraints on various aspects of the study, including: scale, sampling windows, validity of the data and the realism of the interactions. Froehlich *et al* [3], categorized the current approaches of mobile data collection into *direct observations, in-situ self-reports* and *automatic logging. Direct observations*, require the researcher shadow the participants while they interact with the device, as used in [6]. Unfortunately, it does not scale well and restricts the data collection opportunities to conventional time intervals and acceptable observation locations. With that said, this approach allows the collection of real-world interactions, providing researchers with detail context for the nature of these interactions. *In-situ self-reports,* such as interaction diaries, can also be used to obtain insights into the real-world nature of technology usage. While the approach scales to support larger sample sizes and enables greater freedoms on data sampling windows, it does require a large amount of participation and effort from the users. Furthermore, diary entries are rarely recorded in the moment, often resulting in a loss of precision and context surrounding the events – without which it is challenging to attribute interaction behaviors to particular device or environmental factors. *Automatic logging* of the device sensors can be used to perceive environmental factors e.g. ambient light and noise levels. Similarly, logging the device interactions can provide precise details of usage behaviors and times, for example, application launch patterns [2]. However, while the researchers were able to capture the natural app usage patterns of mobile devices, due to technical limitations, they were not able to record the low-level touchscreen inputs or access details surrounding the application interfaces themselves. In contrast, through instrumentation of experimental applications, it is possible to obtain low-level interactions as they are passed to the interface [4,5], but data collection is limited to interactions with the experimental applications only. Moreover, *automatic logging* of device interactions does not provide an accurate measure of the user's intent, and additional steps are required [5].

While none of the current data collection approaches contribute a complete solution, they do provide a set complimentary strengths and weaknesses. Based on these existing collection methods, we developed a set of requirements for the TinyBlackBox framework.

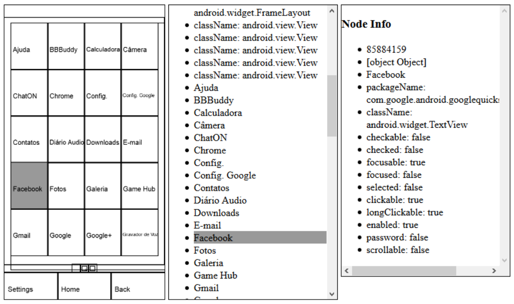

Figure 1. TBB Player - App drawer with interface element details

3. TINYBLACKBOX

TinyBlackBox (TBB), is a standalone Accessibility Service, built for the Android 4.0+ OS. Once installed and activated, TBB will continuously run in the background of the OS, capturing the user's device interactions system-wide. We leverage the Android AccessibilityServices to scrape application data, including page layouts and interface elements – these are represented in a DOM tree structure, revealing information about the nesting of interface elements. TBB records also all of the interface interactions e.g. clicks and swipes made within the applications. In addition to recognizing interface clicks, TBB provides overwritten touchscreen drivers. This enables the framework to receive the sub-gesture touch *begin*, *move* and *end* interactions, as typically recorded for touch offset modeling, and gesture analysis [5]. TBB automatically segments the user interactions into *sessions* based on the screen on/off behaviors. To maximize device performance, log files exist within working memory until the screen goes off, at which point they are written locally into text files. We ensure the security of user data by encrypting the log files locally on the device before they are transmitted using HTTPS protocols. TBB supports parameterized levels of data encryption i.e. encrypt all text, only user generated content, or nothing. We believe it is vital that the user is not only aware of what data is being recorded, but also entirely in control, as such; in future versions we plan to include application specific encryption rules. We have integrated TBB with Google Cloud storage to aggregate log data from multiple participants while the study is live. TBB will only attempt to synchronize with the cloud storage when the device has an active WiFi connection, at least 40% battery remaining and the device is inactive or charging. Prior to uploading log files, they are compressed for network performance and to minimize cloud storage costs. In addition to transmitting the users' log files, TBB will periodically ping the cloud storage servers with the current session number and status report. We use this to verify that TBB is functioning correctly and that the participants are using the devices regularly – this can help reduce the need for researchers to conduct field assessments of the devices and software.

While we present TBB as a standalone data collection service, we recognize that there is often the need for study specific information to be gathered. To support this need, we have also developed a lightweight Android library that can be embedded into 3rd Party applications and services. We provide an API to facilitate communication with the standalone TBB service, enabling researchers to capture additional data logs along side, and synchronized with the other TBB data.

Finally, we have developed a suite of analysis tools to support data extraction, visualization and playback. Since TBB captures the device interactions into individual text files, we have created scripts to rebuild the logs into a local MySQL database. In this form it is possible to extract high-level statistics, such as application usage behaviors. To assist the deeper inspection of individual device sessions, we created TBB Player, an interactive web-based playback tool (Figure 1). TBB Player, renders a wireframe of the mobile screen content that was visible to the user and replays their touchscreen interactions in real-time. Researchers can pause and rewind interactions for further inspection. This tool is particularly useful for investigating gesture interactions that are context-specific because each step of the device interaction is captured.

4. CONCLUSIONS AND FUTURE WORK

There is a demand for mobile HCI evaluations in-the-wild, particularly when investigating the interactions of populations with highly variable abilities and diverse needs. In this paper, we have explored the challenges of conducting mobile in-the-wild user studies, highlighting the strengths and weaknesses of current approaches to gathering data. In support of this demand and to address these weaknesses, we present TinyBlackBox, our standalone mobile data collection system, with analysis and interaction playback tools. We have successfully conducted a four-month user study with novice blind users, exploring their adoption experiences [8] and text-entry performances [7] using TBB. The tool supported a deeper comprehension of the interactions and habits faced by the users in their day-to-day usage, along with a low-level analysis of their finer-grained interactions with the onscreen keyboard and text-entry behaviors. TinyBlackBox is open source software, for the source code and documentation please see: http://goo.gl/VQTrJt

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