A Tool for Conducting User Studies on Mobile Devices

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ABSTRACT
With the ever-growing interest in the area of mobile information retrieval and the ongoing fast development of mobile devices and, as a consequence, mobile apps, an active research area lies in studying users’ behavior and search queries users submit on mobile devices. However, many researchers require to develop an app that collects useful information from users while they search on their phones or participate in a user study. In this paper, we aim to address this need by providing a comprehensive Android app, called Omicron, which can be used to collect mobile query logs and perform user studies on mobile devices. Omicron, at its current version, can collect users’ mobile queries, relevant documents, sensor data as well as user activity and interaction data in various study settings. Furthermore, we designed Omicron in such a way that it is conveniently extendable to conduct more specific studies and collect other types of sensor data. Finally, we provide a tool to monitor the participants and their data both during and after the collection process.

KEYWORDS
mobile search; context; user study; field study; mobile app; sensors

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1 INTRODUCTION
With the technological advances in developing mobile devices, we witnessed an evolution of mobile devices as well as the ways people access information through these devices. Research on mobile information retrieval (mobile IR) is aimed at “enabling users to carry out, using a mobile device, all the classical IR operations that they were used to carry out on a desktop” [8]. The evolution of mobile devices as well as their applications (a.k.a. apps) not only enables users to carry out the “classical IR” tasks on their mobile devices, but also identifies new methods of interaction and information access.

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and field studies. It can also serve as a light-weight mobile search engine allowing researchers to collect mobile query logs. Moreover, Omicron provides a simple way of configuring its background data collection service. The background service collects raw sensor data as well as high-level user activity information together with user interaction data while they use the app. Therefore, in this paper we aim to:

- Familiarize the reader with the Omicron app and the monitoring dashboard.¹
- Give an overview of the architecture and the implementation details.
- Elaborate on the usefulness of our system in relation to the need of an open-source customizable tool to conduct reproducible user studies.

Successful deployment and use of Omicron in our previous experiments indicates its usability as a tool for both conducting user studies and collecting search logs on mobile devices.

2 OMICRON

Here we present the details of the user interface, collected data, and implementation of Omicron.

System overview. An overview of the system is presented in Figure 1. As we can see, the user interacts with Omicron, while the app reads and stores the data on a cloud service (i.e., Google Cloud). It is worth noting that Omicron stores raw sensor data, as well as user interaction data on Google Cloud Storage. On the other hand, it reads and updates the task-related data in the Firebase Realtime Database. This choice was motivated by the relative cost and effectiveness of the two services to store a large amount of data as both services do not require building and maintaining the infrastructure and offer a usage-based billing plan which make them serviceable for large-scale studies and convenient for small ones. Finally, as we see the data analysis and monitoring component retrieves the data from the cloud server and visualizes it, which could be helpful for monitoring an ongoing study.

User interface. Omicron presents itself depending on the action that the participant is required to take. After a short tutorial (Figure 2a), a demo task plus a demographic and background survey, participants are presented with a screen where they can freely search and test the application. The app guides the participants by showing an informative text and by hiding non-required actions at every step. When the user receives a task via a notification, the main screen changes and awaits that the participant starts the task (Figure 2b). Figure 2c shows a sample mobile SERP where the participants consult search results and bookmark the ones that helped them complete the task. This screen is reached when the participant starts a task. Finally, as we see in Figure 2d, similar to an optional pre-task questionnaire, the participants is required to complete a post-task questionnaire.

Collected data. Apart from the participants’ input data, Omicron also collects their interactions within itself (i.e., taps and scrolling). Moreover, a background service constantly collects the phone’s sensors data. In summary, Omicron collects the following sensor data:

- GPS
- accelerometer
- gyroscope
- ambient light
- WiFi
- cellular

Furthermore, it collects other available phone data that can be used to better understand a user’s context. The additional collected data are as follows:

- battery level
- the screen on/off events
- apps usage statistics
- apps usage events

Note that apps usage statistics indicate how often each app has been used in the past 24 hours, whereas apps usage events provide more detailed app events.² Apps usage events record user interactions in terms of:

- launching a specific app
- interacting with a launched app
- closing a launched app
- installing an app
- uninstalling an app

This service collects the data at a predefined time interval and securely transfers it to the cloud service.

2.1 Implementation Details

Omicron is created as a tool to conduct task-based user studies. It is crucial to have a way to schedule tasks, have a search interface to execute queries (in our case we used Bing) and gather sensor data at the end of the study.

Tasks. A task is defined by an ID, a start time and end time, a title, a description and a series of metadata (e.g., the time the participant start the task). For instance, we could have a task with the title “Food” and in the description specify that the participant will need

¹Code available at: https://github.com/aliannejadi/Omicron
²https://developer.android.com/reference/android/app/usage/package-summary
to search for a recipe for dinner. We would then set a date and we would specify an interval of hours in which this task will need to be completed.

A task can be defined in various ways. For instance, each participant can have a series of tasks assigned to them on a particular day. The way tasks can be assigned to a participant or a group of them is via the application ID, an identifier generated from the instance of the installation of Omicron. Tasks can be changed or added during the experiment and they can be rescheduled if the participant does not manage to do them in the assigned slot.

**Configuration.** Omicron can be customized by editing a single configuration file. Listing 1 is a small excerpt of the configuration file. It can be seen that the gathering of the various data can be conveniently switched on or off. The interval for sampling or transferring the data can also be modified easily. It is also possible to set the link for a survey after the installation and pre- and post-task questionnaires. Some of the sensor data can be chosen to be transmitted only over WiFi to consume less mobile data.

**Dashboard.** To be able to monitor the ongoing status of the study, we have built a small Web dashboard. This might be less needed for in lab studies since one can observe participants directly. In the field study setting, however, it is critical to monitor the progress of the study. We found it to be particularly useful to know when a participant was lost (the result of the queries did not answer the task) or if there was a problem in data collection. Jointly with a standard crash and error reporting dashboard, this gave us an overview of how the study was proceeding. Figure 3 shows one of the tables that correlated the queries with some of the other data that we collected. The dashboard is made in Python and Dash.

Although is not possible to personalize it graphically, it is relatively easy to convert Jupyter Notebooks.

### 3 USABILITY

We developed Omicron as part of our effort to conduct an in-situ user study on smartphones. We carefully took the required measures in developing an app that runs smoothly on a large variety of Android devices. More importantly, since the participants had to install the app on their phones, we aimed to design an efficient application that does not affect the people’s everyday usage experience. Therefore, we aimed to develop Omicron in such a way that it would not slow down the device, would not consume much energy, and would recover from possible crashes without user’s involvement.

While conducting our previous studies [1, 2], Omicron was successfully installed and used by over 350 users worldwide. Throughout the studies, we continuously monitored the collection of data, as well as the performance of the app. Several bugs were addressed throughout the study quickly, accompanied by app updates on the Play Store to ensure a positive experience of the participants. We used Omicron to conduct an in-situ user study where we asked the participants to perform pre-defined search tasks [1]. In another effort, we used the Omicron’s background service and extended the UI to collect a mobile query search log [2]. We see in Figure 4 the number of reported queries, as well as users who installed and used the app on their phones during this study. It is worth noting that during these studies, Omicron collected and stored over 350 GB of data on cloud servers. In both studies, Omicron was installed and
used on multiple smartphones from various manufacturers featuring different versions of Android OS. These successful experiences enforce the usability of Omicron in the community.

Our software design allows for easy extension to collect sensor or user data that would emerge in the future. Also, the UI can be easily modified to be used for other types of studies. For instance, one could add a voice-based interface to Omicron for user studies based on spoken conversations. Notice that we have tested Omicron only for field studies and on personal phones; however, nothing limits it to be used for controlled lab studies. Therefore, one could use Omicron in a much more controlled experimental settings. The design of the app, as well as the database of tasks, allows for several use cases, not to mention the possibility of extending the current version for a more specific need.

4 CONCLUSIONS AND FUTURE WORK

In this paper we introduced Omicron, an app to collect mobile query logs which includes other system information about the task, and perform user studies on mobile devices. We gave a brief overview of the application and the various components that are part of the architecture. We showed how each piece fit together and how to customize Omicron to conduct a study. Writing a mobile app is expensive and time-consuming. Omicron offers a starting point for the researchers in the community to develop their required study apparatus on top of Omicron, without worrying about a bespoke application. Furthermore, we have designed Omicron to be easy to customize so that it can adapt to the needs of different studies. It can also be easily configured to perform other types of studies, or be used as a simple tool to collect mobile query log. Finally, it is worth noting that Omicron provides the ground towards more reproducible studies.

In the future, we plan to extend Omicron to be modular and explore gamification for mobile data collection. One of the challenges of building an application that can be reused for different types of user studies is that for instance, one study might need to gather sensor data but it would not make use of the search feature. Unfortunately at the moment, it is hard to do it without adventuring in the code base and knowing Android programming. The architecture could be made more modular to allow both the reuse of low-level components and graphical components, doing this could allow easier reuse of Omicron even for studies that differ considerably from what it was created for. As we know, it is difficult to gather enough participants to conduct mobile IR studies at large scale. By making the studies open via mobile app stores it is possible to sample from a vast audience as shown in studies like [10] and [13]. Every study would need to adapt game elements in a way that incentivize participants to take part in their studies. Therefore the type of study would dictate a different approach. However, there are known game elements that can be reused in many studies, for instance leader boards and points. Also, we plan to extend Omicron to enable studies on conversational search on mobile devices [4].

ACKNOWLEDGMENTS

This research was in part funded by the RelMobIR project of the Swiss National Science Foundation (SNSF). We would like to thank Jacopo Fidacaro, who helped us in developing Omicron as part of his summer internship. Also, we would like to thank Morgan Harvey and Matthew Pointon for their feedback on the app’s design.
REFERENCES

[1] Mohammad Aliannejadi, Morgan Harvey, Luca Costa, Matthew Pointon, and Fabio Crestani. 2019. Understanding Mobile Search Task Relevance and User Behaviour in Context. In Proceedings of the 2019 Conference on Human Information Interaction and Retrieval, CHIIR ’19. ACM, 143–151.

[2] Mohammad Aliannejadi, Hamed Zamani, Fabio Crestani, and W. Bruce Croft. 2018. In Situ and Context-Aware Target Apps Selection for Unified Mobile Search. In Proceedings of the 27th ACM International Conference on Information and Knowledge Management, CIKM ’18. ACM, 1383–1392.

[3] Mohammad Aliannejadi, Hamed Zamani, Fabio Crestani, and W. Bruce Croft. 2018. Target Apps Selection: Towards a Unified Search Framework for Mobile Devices. In The 41st International ACM SIGIR Conference on Research & Development in Information Retrieval, SIGIR ’18. ACM, 215–224.

[4] Mohammad Aliannejadi, Hamed Zamani, Fabio Crestani, and W. Bruce Croft. 2019. Asking Clarifying Questions in Open-Domain Information-Seeking Conversations. In Proceedings of the 42nd International ACM SIGIR Conference on Research and Development in Information Retrieval, SIGIR ’19. ACM, 475–484.

[5] Juan Pablo Carrascal and Karen Church. 2015. An In-Situ Study of Mobile App & Mobile Search Interactions. In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems, CHI ’15. ACM, 2739–2748.

[6] Karen Church, Barry Smyth, Keith Bradley, and Paul Cotter. 2008. A large scale study of European mobile search behaviour. In Proceedings of the 10th Conference on Human-Computer Interaction with Mobile Devices and Services, Mobile HCI ’08 (ACM International Conference Proceeding Series). ACM, 13–22.

[7] Fabio Crestani and Heather Du. 2006. Written versus spoken queries: A qualitative and quantitative comparative analysis. JASIST 57, 7 (2006), 881–890.

[8] Fabio Crestani, Stefano Mizzaro, and Ivan Scagnetto. 2017. Mobile Information Retrieval. Springer.

[9] Morgan Harvey and Matthew Pointon. 2017. Searching on the Go: The Effects of Fragmented Attention on Mobile Web Search Tasks. In Proceedings of the 40th International ACM SIGIR Conference on Research and Development in Information Retrieval, SIGIR ’17. ACM, 155–164.

[10] Niels Henze, Benjamin Poppinga, and Susanne Boll. 2010. Experiments in the wild: public evaluation of off-screen visualizations in the Android market. In Proceedings of the 6th Nordic Conference on Human-Computer Interaction ‘10. ACM, 675–678.

[11] Maryam Kamvar and Shumeet Baluja. 2006. A large scale study of wireless search behavior: Google mobile search. In Proceedings of the 2006 Conference on Human Factors in Computing Systems, CHI’06. ACM, 701–709.

[12] Maryam Kamvar and Shumeet Baluja. 2007. The role of context in query input: using contextual signals to complete queries on mobile devices. In Proceedings of the 9th Conference on Human-Computer Interaction with Mobile Devices and Services, Mobile HCI ’07 (ACM International Conference Proceeding Series), Vol. 309. ACM, 405–412.

[13] Donald McMillan, Alistair Morrison, Owain Brown, Malcolm Hall, and Matthew Chalmers. 2010. Further into the Wild: Running Worldwide Trials of Mobile Systems. In Pervasive Computing, 8th International Conference, Pervasive ’10. Springer, 210–227.

[14] Timothy Sohn, Kevin A. Li, William G. Griswold, and James D. Hollan. 2008. A diary study of mobile information needs. In Proceedings of the 2008 Conference on Human Factors in Computing Systems, CHI’08. ACM, 433–442.

[15] Yang Song, Hao Ma, Hongning Wang, and Kuansan Wang. 2013. Exploring and exploiting user search behavior on mobile and tablet devices to improve search relevance. In Proceedings of the 22nd International World Wide Web Conference, WWW ’13. ACM, 1201–1212.