Modular Human-Computer Interaction Platform on Mobile Devices for Distributed Development

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Abstract. For people with visual disabilities, mobile devices have become an indispensable part for independent and self-determined living. Increasing performance of mobile devices and availability of mobile sensors and actors can improve the usability and applicability of mobile solutions. The wide range of modalities available for communication and interaction with mobile devices increase the gap between Human-Computer Interaction (HCI) research and actual implementation on mobile devices. We propose the use of a Domain Specific Language to enable the distributed development of modular and individually adaptable HCI implementations on an improving and exchangeable mobile platform.

Keywords: Human-Computer Interaction, Mobile Computing, Development Cycle, Multi-Modal Interaction

1 Introduction

The availability of versatile mobile computing platforms with wireless connectivity opened new Human-Computer Interaction (HCI) models for blind users making mobile devices like smartphones an indispensable helping device. Following [1], usable information starts with localization, object detection, beacons, body orientation, and many more, and does not end with recent advances in image recognition, that is now available on mobile platforms. Already in [2], demand for the design of user interfaces for all, raises the need of new development and evaluation cycles to keep track with technological and scientific advances, and to maintain solutions. There are still many open question of research into multi-modal non-visual interaction [4], and how experiments can be designed and suitable developed given the rich sensory information of mobile platforms. This concludes to a user-centered design process [3] to recognize and understand individual capabilities, and accommodate to them during development. This paper presents a solution, where a user-centered design is feasible by abstraction of data sources, sensors and actors using a Domain Specific Language (DSL). The

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shortened development and distribution cycle enables distributed HCI experts implement, and experiment with modalities, while users and testers validate the approaches for immediate feedback. At the same time, hardware and mobile developers improve its implementation for several operating systems. The development of this platform is supported by the German Bundesministerium für Bildung und Forschung (BMBF).

2 Problem Statement and Related Work

The survey papers [3,4] mention various mobile solutions to assist people with visual disabilities. In contrast to them, the developed platform does not aim at a specific application, and offers general programmatic access to data networks, provided sensors and actors to communicate with the user.

The main aim is to enable distributed development, testing and evaluation of multi-modal HCI models on mobile devices for several platforms, support both sensors and actors on mobile devices, and external devices such as orientation sensors, vibration bands and mobile Braille displays with low-latency responses.

3 Methodology

Integral part of the platform is the use of a DSL to enable full versatility how data is processed, how the user is informed, and how the system reacts to user interaction. The DSL should enable full access to sensors, actors and data, while each module is encapsulated from other HCI models and modules. A main aspect is the abstraction of access to data, sensors, actors and external hardware from the actual HCI modules. Furthermore, special care was needed to manage access to serialized actors, such as the narration unit for mobile devices. Using priority queues, the modules can inform about severity of information, to help the system which information to deliver first.

This structure also promotes the distribution of the development, which is enabled by a client-server approach, where developers can easily upload their modules to a server, which is queried by all installed clients that are permitted access to development version. This reduces the time for development updates from the HCI side to clients a matter of less than a minute. All modules have four states: paused and unregistered, registered and inactive, active and muted, active. Every module needs to be registered, activated and unmuted before using the module within the system. This behaviour promotes easy testing of different modules, since they can be loaded individually.

Another advantage of modular development and the usage of the DSL is the abstraction from app programming itself. This allows people with different implementation skills to contribute their experience in the design of barrier-free HCI interfaces without having pronounced programming skills. As an example, modules can offer nearly unlimited individualization for users, and simplify testing and evaluation of various HCI modes just by switching in options. Listing 1.1 shows an example of two menu options for a haptic anklet by defining the vibration intensity as a number and the delay between two vibrations. Default values can be set with the `value` parameter. These simple manipulations of the options and the short update cycles allow a quick adjustment and testing of the modules in direct and immediate feedback with actual users, which promotes efficient and a new level of user-centered programming.

```
function registerModule()
 local moduleOptions = {
  vibInt = {
   label = {de = "Intensitaet [%]",
            en = "Intensity [%]" },
   description = {de = "Staerke der Vibration", en = "Strength of vibration"},
   kind = "entry:number",
   value = "30"
  },
  vibrationDelay = {
   ...
   kind = "entry:number",
   value = "1500"
  }
 }
```

Listing 1.1. Register function in theModule Options

Also, modules may read available sensors on demand, or are informed about changed readings via call-back functions, enabling fast responses to changed conditions or requests.

4 Results

The development platform has already been tested by implementation of several HCI modules for aiding blind persons in their urban mobility, or help researching HCI modalities: A module for a simple acoustic compass informs the user about the heading of the smartphone, in degrees, cardinal directions or in clock directions. A so-called radar module informs about objects or points of interest that are registered in OpenStreetMap or a city administration database in a circular pattern. For free space traversal, a module supporting GPS and compass orientation helps to reach a point in a given distance and heading, using narrative output or haptic feedback. Using a routing module, the user can be guided on a computed path between two points supporting safe pedestrian routing.

Additionally, various hardware was successfully accessed over Bluetooth by modules, such as vibration bands for arms or feet, or orientation sensors such as the TI SensorTag to easily query head or body orientation. For efficient sonification, an analogue synthesizer simulation and head-related transfer function support offer a wide range of acoustic feedback. A communication protocol to a computer with state-of-the-art neural-network optical object detection was successfully established. Finally, yet importantly, a mobile Braille display is supported, to give haptic feedback to the user.

The app programmers provided the framework for all these modules, so that experts in supporting barrier-free interactions with the external devices could easily implement the individual modules. For example, the focus could be placed on the design of vibration patterns, which optimally support a user in a navigation task by implementing the control of the individual vibration motors at various events in a vibration module without having to have detailed knowledge of application programming. Since no extensive programming environment needs to be used to develop the modules, people with visual impairment or people without programming skills can efficiently participate in the development of the app without having to familiarize themselves with IDEs. This approach is currently successfully used in a diversity team of seeing and blind developers, skilled app developers and HCI experts.

Finally, a simulation module offered an efficient platform for Wizard-of-Oz tests for successfully evaluating the usage of the app with its various modalities to inform the user about routing hints and obstacles. The test was carried out with ten visually impaired users and shows that not only can the development be made efficient and barrier-free, but also that the app is promising as an application in the area of support for the visually impaired.

5 Conclusion

The modular HCI platform for mobile devices has proven its applicability, supporting multi-modal, user-centered and customized feedback to the user. Its extensibility offers more hardware sensors, actors, as well as mobile platforms to be integrated. In addition, other groups may provide HCI modules to the platform, enabling fast development, evaluation and testing cycles for new solutions to aid people with visual disabilities in their independent and self-determined life.

Depending on its distribution platform, some large manufacturers do not allow uploading new code on installed systems at the end-users. This seems a drawback to the original approach to fast development and distribution cycles. Actually, this does not influence the development phase, where real-time update are not forbidden. For end-users, the well-tested modules will be distributed as App updates as included code.

The platform is an integral part of the TERRAIN Project[4], helping visually impaired humans for a self-determined and individual mobility in an urban environment.

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[4] `http://www.terrain-projekt.de/`, federally funded by BMBF, 07/2016–06/2019