# Enhancing accessibility: mobile to ATM case study


Marc Pous, Circe Serra-Vallmitjana,
Rafael Giménez, Marc Torrent-Moreno
Barcelona Digital Technology Centre
Barcelona, Spain
{mpous, cserra, rgimenez, mtorrent}@bdigital.org

David Boix
Usability Department
e-la Caixa
Barcelona, Spain
dboix@elacaixa.es



*Abstract* — **People with disabilities encounter daily many barriers that prevent them to interact with electronic devices in their surroundings. The INREDIS project has designed a cloud based platform to overcome these challenges by turning mobile devices into personalized and universal remote controls. In more detail, the INREDIS platform is capable of identifying the user needs, personalizing the mobile phone interface to enable multimodal HCI and interacting with the target device. In this paper we describe the design, implementation and evaluation with real users of this accessibility platform in a banking environment. The developed prototypes depicted in this paper provide multimodal interfaces for people with visual and motor difficulties so they can execute some banking services at an ATM by interacting with their smartphone or computer. Tests results and optimistic user's feedback confirm that the use of a mobile device could enable a more secure and accessible mode to interact with indoor and outdoor devices.**



***Multimodal interaction; Accessibility; Accessible mobile interfaces; Banking services***


## I. Introduction

Currently, people with disabilities find many difficulties to perform the most common daily tasks. In such scenarios, technology, far from providing always a solution, sometimes raises the existing barriers. Several reasons and challenges exist, where the main issues refer to a lack of standards with respect to accessible ICT interfaces and the wide diversity of requirements brought by the wide variety of special needs of potential users.

The INREDIS project was conceived to design a universal solution capable to provide accessible and personalized ICT interfaces for any kind of electronic device. The main idea behind the project is to develop a cloud-based architecture able to interact and control any target device and provide its personalized and accessible interface through the user's mobile device (or another device owned by the user) according to its needs and preferences. Such system would guarantee that any compliant device (i.e., that could interact with the INREDIS platform) would be automatically accessible without the need of taking into account all specific needs associated to any disability during the design phase, and that it would always benefit from the latest updates.

In this paper, we focus on the banking environment and, more specifically, to cash machines where the common "one-size fits all" approach makes it difficult for people with certain disabilities to interact with them. Note that some existing ATMs already provide some accessibility features, such as specific sizes for wheelchair users or Braille-enabled keyboards. The more advanced may include jacks to plug in headphones for blind people or aid videos with sign language for deaf users. However, the small amount of special needs addressed and the lack of a legal framework of standardization among them clearly imply that a more holistic and global solution is required.

In this scenario, we explore the benefits of using a mobile phone or computer, owned and well known by the user, to manage ATM services. With such goal in mind, we first performed a set of tests and interviews in order to identify the main challenges encountered by the different profiles (or disabilities) and match them with potential assistive technologies (Section III). Based on this analysis, and on the INREDIS platform, we developed a prototype to be used to withdraw money from the ATM by two selected users' groups; people with visual impairment and people with limited mobility (Section IV). Finally, we evaluate the system with real users making use of well defined methodology (Section V) and outline the main conclusions and future lines of work (Section VI). Before describing the contributions of this paper, we set the context of our work, introducing the INREDIS project and its software architecture (Section II).

## II. Related Work and Background

Many of the electronic devices currently deployed on public environments fail on providing a properly accessible operation mode for the heterogeneous user profiles which can be found in today's cities. We can observe how current Public Digital Terminals (PDT) [2], such as, ticket machines, cash dispensers or interactive kiosks, are mostly not accessible at all. However, new generations of technologies are rising trying to offer solutions to address these accessibility problems that exist in our society. On the one hand, research projects such as AEGIS [7], OASIS [8], ASK-IT [9], among other, propose standards and new approaches of existing technology to improve the accessibility in specific environments. On the other hand, organizations and corporations, such as Microsoft [4] or Google [10], work on accessible and multimodal initiatives with the aim of improving their technology.

The INREDIS project, which is the framework for the research described in this paper, addresses a new approach to the application of accessible technologies. It tries to break the current trend, where technological advances in accessibility are usually product modifications aimed at making the product usable to people with disabilities. INREDIS aims to take a technological leap developing a cloud based system able to interact with all (connected) devices in order to provide multi-modal and accessible interfaces for all of them through a mobile device such as a smartphone. Such system should be capable of adapting the user device graphical interfaces and the interactive assistive technologies dynamically without requiring a tailored device. This universal interoperability platform will be, therefore, able to adapt to new market standards while maintaining compatibility with earlier systems, as well as ensuring ease of use and universal access at all times [1].

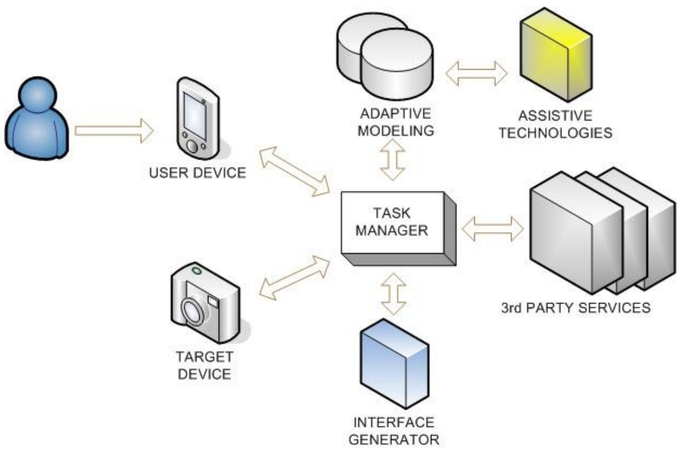


Figure 1. INREDIS architecture

Figure 1 draws the resulting architecture of the INREDIS project. The main building blocks implemented in the INREDIS platform are the Task Manager, the Adaptive Modeling with a set of Assistive Technologies in the cloud, the connector with 3rd party services [3] and the Interface Generator. Most of the building blocks have been developed as a service encapsulated into an OSGi bundle. The INREDIS platform is based on a SOA (Service Oriented Architecture) and EDA (Event-driven Architecture) paradigm.

The *Task Manager* serves the requests from the users to the target service, or device, through the INREDIS hub. All user's requests need the user ID (generated by the Adaptive Modeling building block), the device ID and the target service or device that want to be consumed (e.g. when the user wants to turn on the television, the television is the target device). The reply of the Task Manager after all the processing is an interface adapted for the specific user's device, with the necessary assistive technologies enabled and with all the content generated by the target service or device.

The *Adaptive Modeling* offers the proper tools to generate the user's profile and the algorithms and mechanisms to derive the matching between the user needs, assistive technologies and devices, by means of profiling and recommendation techniques.

The main goal of the *Interface Generator* is to build a proper interface designed for the user and her device. Most of the prototypes developed had defined the abstract interfaces descriptors, based on Kobsa's interface adaptation research described at [5] [6], into the Interface Generator building block. Once the *Interface Generator* receives a request for an interface, it adapts the abstract descriptor with the proper content to the specific user device. The INREDIS platform allows all the target services and devices to develop an adaptor module to provide accessible and multimodal interfaces to the users and devices.

Finally the *3rd party services* are general services which offer information of the user's environment and can be consumed through an API. Although the INREDIS project covered several use cases, such as urban, learning and working environment, house automation, among others, we will focus in the following sections on the banking environment.

## III. User Needs and Assistive Technologies

Following the user-centric design principle used along the complete project, we executed, on first place, a study to detect the barriers faced by different groups with disabilities when operating with different banking channels: ATMs, online banking, and mobile banking.

We started a series of user tests and interviews with representative entities [1] of the following groups: visually impaired, hearing impaired, physically impaired (with some dexterity and motor disability) and elderly. While identifying the existing barriers, we defined the potential solutions, both from a technological and usability perspective, for each profile and channel. User tests at this stage helped us to refine and deepen in the resulting conclusions which are depicted in TABLE I for each profile:

TABLE I. Results of the Interviews

| Profile | New requirements |
|---|---|
| Visually impaired | • Access to information through touch or sound signals.<br>• Acoustic information of the operation.<br>• Web accessibility for online banking (certification of web pages): reduction of images and options clearly identifiable.<br>• Enhanced security and privacy at the ATMs. |
| Hearing impaired | • Ability to communicate with the bank's staff in case of a problem.<br>• Alternative to acoustic signals.<br>• Simplification of financial messages in ATMs, online banking and mobile banking.<br>• Assistive information with sign language. |
| Physically impaired | • Enhanced physical accessibility of the ATM interfaces.<br>• Enhanced Security and privacy at the ATMs.<br>• Simplification of the interface in order to be able to use special assistive technologies (iris control, head control, etc.). |
| Elderly | • Simplification of operations, both understanding and realization.<br>• Enhanced security at the ATMs.<br>• Longer timeouts to complete operations.<br>• Easier interfaces (e.g., larger buttons). |

After that, we analyzed the existing assistive technologies and defined the most appropriate match with respect to user device and interaction mode for all envisioned banking scenarios of

[1] The involved entities were: COCARMI, FESOCA, FECOM, ASEM, ACAPPS, CAG, APPC, ASPACE and ESCLAT.

the project (i.e., banking channels and disability profiles), see TABLE II.

TABLE II. PROTOTYPES TO VALIDATE THE INREDIS PLATFORM IN BANKING ENVIRONMENT

| Channel | Profile | User device | Assistive technology |
|---|---|---|---|
| ATM | Visual impaired | Mobile phone | Voice synthesis |
| | Physical impaired (severe motor disability) | Laptop | Eye-tracking<br>Easy physical interface |
| Online banking | Hearing impaired | Laptop | Video on sign<br>Easy language<br>Pictogram |
| | Physical impaired (severe motor disability) | Laptop | Eye-tracking |
| | Elderly | Laptop | Easy language<br>Pictogram |
| Mobile banking | Physical impaired (dexterity disability) | Mobile phone | Voice recognition<br>Easy physical interface |
| | Elderly | Mobile phone | Voice recognition<br>Pictogram<br>Easy language |

## IV. System Design and Development

Although all scenarios depicted in TABLE II were developed and tested within the project, in this and the following sections we will focus on the ATM scenarios. These are the most interesting and complex from an implementation perspective since the user's mobile device will directly interact with a PDT, an ATM in this case, and aim to enhance users' autonomy in outdoor scenarios.

With the aim of building these prototypes, changes in the implementation of an ATM in a lab environment, a mocked version of the corporate banking systems and local connectivity were necessary. A Bluetooth[2] interface was built in the lab ATM, in collaboration with the company responsible of the cash machine's HW and SW developments, to be able to create a direct communication channel with the mobile device. During the prototypes definition, we described with them the XML interfaces between the mobile device, the bank's corporate systems, the INREDIS platform and the ATM. Because of the security constraints related to the banking environment a mocked version of the corporate banking systems was developed. This mock version provided the backend operations required for demo purposes. The connection between the mobile device, the INREDIS platform and the mock version of the corporate systems was implemented through a local and secure WiFi.

The user application for blind people was implemented on Android mobile devices. The arguments for choosing Android platform were related to the built-in assistive technologies available for the platform and the open source license enabling the creation of new ones. At that time, we opted for the Android 2.1 version to develop the prototype of the mobile device, since it provides text-to-speech capabilities in Spanish. In order to select the device, a previous analysis was performed to decide on the best available device from an accessibility point of view. The Motorola Milestone was selected, having a physical keyboard and a directional pad to allow accessible navigation through the application without using the touch screen.

People with severe motor disability used a laptop integrated into their wheelchairs with Windows operating system. Some users tested eye-tracking technologies, facial mouse and joysticks as assistive technologies under the same GUI. Note that although still many people with severe motor disability have no laptops integrated in their wheelchairs, it is an emerging trend and more companies are offering eye tracking products as an appropriate interactive system in order to enhance the autonomy of people with limited mobility[3].

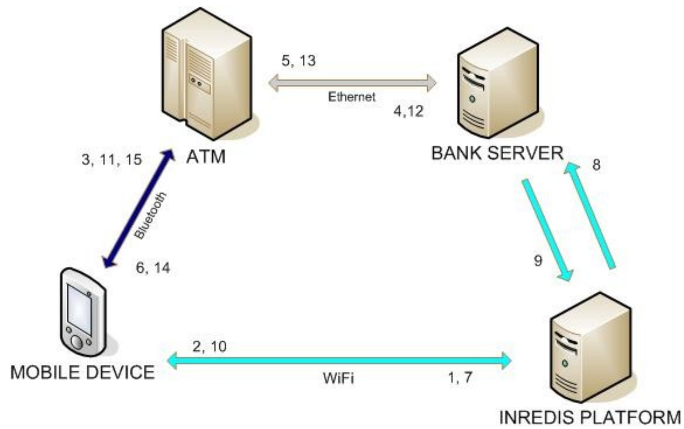


Figure 2. Prototype workflow diagram

We can see in Figure 2 the implemented workflow in our banking scenario. The first action taken when a user places herself in front of the ATM is their identification (1) against the INREDIS platform via username and password through their mobile device. After the successful login process, the INREDIS platform will be able to retrieve a user profile (*Adaptive Modeling*) in order to know her needs and preferences (2). The *Interface Generator* process will include a GUI adaptation process and the multimodal interaction matching with the available assistive technologies at the user's device. From this moment, the user would use the bank application through the INREDIS platform, the bank's corporate systems and the ATM will be the target devices.

In the case of blind users, the INREDIS platform would become aware of the text-to-speech technology available in the mobile phone, so the *Interface Generator* will enable it. In the case of limited mobility users, the INREDIS platform would detect the eye-tracking technology enabled, and then, the *Interface Generator* will enlarge the size of the buttons and text inputs of every GUI.

[2] Although NFC (Near Field Communication) was the first choice due to its envisioned future commercial use we could not obtain an NFC development kit and equipped cell phone at the implementation time.

[3] http://www.cisionwire.com/tobii-technology-ab/r/tobii-unveils-the-world-s-first-eye-controlled-laptop,c550419

Thereafter, users would have to identify themselves with the ATM (3). This action would send the encrypted information of the user's bank activation string stored in the application to the ATM. The cash machine will then verify with the corporate banking systems (4) that the user has permissions to do the operation. If the exchange is successful, the corporate banking systems will send a *session token* to the mobile device to use it during the current session (5 - 6). Indeed the corporate banking systems and the INREDIS platform would know this session token with a short time expiration. This sequence of steps is similar to the one involved in common ATM usage with electronic cards. This exchange of data between the mobile device and laptop with the ATM is performed through the Bluetooth channel. After the confirmation of the user's bank account through the cash machine, the ATM will be aware that someone is interacting with it and the system would block the screen to prevent other users use it or even watch the operation.

Then, users would navigate through the application writing the amount of money they want to withdraw and their secret number (7 – 8 – 9 – 10). Finally, when the operation is accepted by the bank (11 – 12 – 13), the ATM would prepare the money inside the cash dispenser. At this moment the application would show a special GUI to the user that does not appear in a regular ATM operation. The new interface (14) has a button which would allow users to trigger the ATM to dispatch the money at this specific moment (15). The reason behind this new interface is that people with special needs, e.g. visual impairment, need more time to find the cash slot and feel more secure. The designed GUI was reviewed using heuristic evaluation by an expert team which introduced improvements in the usability features and the graphical interface. This GUI also was showed due to the blind users' feedback during the design process of the prototypes.

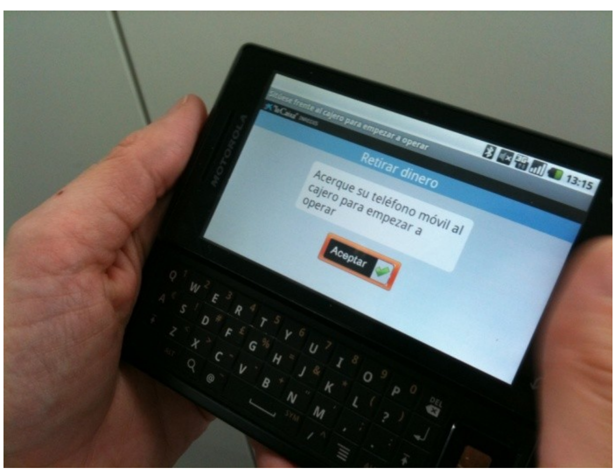


Figure 3. Picture of the application interacting with the ATM

All the withdrawal transactions are safe exchanging XML messages over Bluetooth between the user's device and the ATM and XML over HTTPS through WiFi between user's device, the INREDIS platform and the corporate banking systems. The encrypted token would maintain the user's privacy with the banking services. The INREDIS username and password step would allow the users to do this operation with any mobile device without depending on a specific one. Although the INREDIS server has a secure architecture, the overall security of the banking system and the prototype was not analyzed in detail, as it was not the scope of the development of the prototype.

## V. USER TESTS

Finally, an evaluation phase was conducted where the main goal was to explore the usability and accessibility of the banking environment platform with few real users. The tests examined whether the interfaces, procedures and assistive technologies were appropriate for the selected users to operate with the ATM through a mobile device. The three key aspects to be worked on during the sessions were:

1. Is the user able to perform the assigned task?
2. Does the user notice an improvement in the interfaces?
3. Does the user find the assistive technology provided easy to use?

First, we defined an end to end methodology for conducting user tests. It included:

- Definition of user profiles for testing, establishing criteria for inclusion and exclusion of users.
- Definition of each step for all tasks in each prototype and associated use case.
- Setting the approximate time for completion of each test user.
- Writing a document of consent to carry out the test as well as audio and video recording during the user test.
- Development of a pre-test questionnaire to collect user information (age, education, use of technology, etc.).
- Elaboration a data collection template to register key aspects during the test: task completion time, times asked for help, difficulties encountered, etc.
- Development of a questionnaire for accessibility and usability feedback once the test is finished.
- Definition of a protocol to explain the development of the test before performing the test. This protocol envisaged a few minutes to familiarize the user with the mobile.

These tests were performed at "la Caixa" usability lab, were a real ATM emulating a real environment was prepared (as described in Section IV) and each user performed the test independently. Ultimately, we conducted the complete set of tasks with 7 users: 4 visually impaired (of which 3 were completely blind) and 3 with severe motor disabilities.

The main conclusions that could be drawn analyzing the tests results and the users' feedback are the following:

People with visual impairment operating an ATM:

- They found the GUI very simple and easy to use.

- They realized that with this system it is possible to operate with cash dispensers independently of the ATM model.
- They could operate more safely as they type the PIN on their device and not in the ATM (not knowing if someone is watching).
- They liked very much the possibility to decide when the money came from the ATM, so they could have time to find the dispenser.
- They felt more secure because if the operation showed any anomaly they could know it through the mobile phone.

People with severe physical impairment operating an ATM:

- They found an improvement to make the transaction without having to give the credit card to anyone, and mainly without having to give the PIN information.
- They liked the GUI, simplified with large buttons to operate with their assistive technologies.
- They found the procedure simple and easy to perform with their own laptop.

Obviously, some details were also found which could be improved for future designs, such as more intuitive menus and navigation that the ones developed. All in all, the most relevant difficulty that we could identify during the tests is the lack of familiarity of the users with the new devices, mobile phone with voice synthesis or laptop with eye tracker, and that the latter one, had to be calibrated.

Nevertheless, the objective evaluation parameters were quite successful and matched the expected values, namely:

- Average time to perform tasks: 3 minutes
- Average number of requests for help during the development of the task: 1.4
- Average amount of completed tasks: 100%
- Average amount of correctly completed tasks: 80%

In all the cases, users found a great enhancement operating with ATM because they could interact with the ATM in a more autonomous and secure way.

## VI. CONCLUSIONS AND OUTLOOK

This paper presented an accessibility system which enables people with disabilities (focusing on blindness and limited mobility) to withdraw money from an ATM and execute other banking operations with their own mobile device. The system was conceived involving users with disabilities during the design, development and test. It was based on an interoperable platform in the cloud capable of adapting user interfaces and multimodal interactions depending on personalization techniques in real-time.

The evaluation phase demonstrated that people with visual impairment could operate with the cash machine with text-to-speech coming from a mobile device, independently of the ATM model. People with severe physical impairment could operate with the ATM in a more independent way maintaining their privacy (most important, they do not need to give to anybody their credit card or PIN number).

Still, many steps are necessary to turn INREDIS into a real-life tool for people with disabilities. The most relevant probably are a standardization process and an active collaboration of industry partners and legislative bodies.

With respect to existing assistive technologies, further work is also required in order to deploy device-independent and cloud-based assistive technologies which can robustly work in outdoor and noisy scenarios.

## VII. ACKNOWLEDGMENT

The research performed in this paper was partially funded by CDTI, under the CENIT program, in the framework of the Spanish government's INGENIO 2010 initiative.

## REFERENCES

[1] Marc Pous, Luigi Ceccaroni, "Multimodal Interaction in Distributed and Ubiquitous Computing," in ICIW Proceedings, pp.457-462, 2010 Fifth International Conference on Internet and Web Applications and Services, 2010

[2] Roberto Torena, José Ángel Martínez Usero, "Present and future of eAccessibility in public digital terminals,", European Journal of ePractice, No 10, September 2010, ISSN: 1988-625X.

[3] J. Abascal, B. Boanil, L. Gardeazabal, A. Lafuente, and Z. Salvador, "Managing Intelligent Services for People with Disabilities and Elderly People," Lecture Notes in Computer Science, vol. 5615/2009, pp. 623-630, July 2009.

[4] L. Deng, K. Wang, A. Acero, H. Hon, J. Droppo, C. Boulis, Y. Wang, D. Jacoby, M. Mahajan, C. Chelba, and X. D. Huang, "Distributed Speech Processing in MiPad's Multimodal User Interface," IEEE Transactions on Speech and Audio Processing, vol. 10(8), pp. 605- 619, November 2002.

[5] Kobsa, J. Koenemann, and W. Pohl, "Personalized Hypermedia Presentation Techniques for Improving Online Customer Relationships," The Knowledge Engineering Review, vol. 16(2), pp. 111-155, 2001.

[6] D. Küpper, and A. Kobsa, "Tailoring the Presentation of Plans to Users' Knowledge and Capabilities," Lecture Notes in Computer Science, vol. 2821/2003, pp. 606-617, September 2003.

[7] Peter Korn, Evangelos Bekiaris, Maria Gemou, "Towards open access accessibility everywhere: the AEGIS concept" (Proceedings Volume 12), Invited session entitled "Inherent Accessibility in Software Design, Development and Assessment", HCI2009, San Diego, USA, July 2009

[8] Bekiaris, E., Bonfiglio, S., "The OASIS Concept," Proceeding UAHCI '09 Proceedings of the 5th International Conference on Universal Access in Human-Computer Interaction. Addressing Diversity. Part I: Held as Part of HCI International 2009, San Diego, USA, 2009

[9] Laura Pastor, María García Robleda, Luis Reigosa, Maria Fernanda Cabrera-Umpierrez, Alexandros Mourouzis and Brigitte Ringbauer, "Nomad devices adaptation for offering computer accessible infomobility services," UAHCI'07 Proceedings of the 4th international conference on Universal access in human-computer interaction: ambient interaction, pp. 536-545, Beijing, China, July 2007

[10] T.V. Raman, "Open, Interoperable Means for Integrated Multimodal Interaction," in W3C Workshop on Multimodal Interaction, 2004