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Empowerment of assistive technologies with mobile devices in a DUI ecosystem

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Abstract

Even though mobile devices already play an important role in assisting people with disabilities in their daily and professional lives, there are opportunities to further advances by developing assistive technology with Distributed User Interfaces (DUIs). DUIs empower not only the individual but also the environment. In order to support exploration of this concept, we present a mobile application developed with DUI characteristics in an educational context. We discuss achieved results in the light of the empowerment objective.

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Keywords: mobile technology; assistive technology; device ecology; distributed user interaction

1. Introduction

Empowerment is a concept from social sciences that addresses power relationships in a society, usually applied to the process of minorities assuming their social role and increasing their influence due to the recognition and exposition of their specific abilities. In enterprise management, empowerment is a tool for change, based on three principles: sharing information with everyone, autonomy and self-management.

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Deibel[1] defines empowerment as "A person's ability to freely plan, decide, and act as she deems best".

We build on this concept to address experience with technology, especially assistive technology, considering that technology can be a tool of empowerment. As in Deibel´s definition, technology can empower the individual. Considering assistive technology, user empowerment means that technology is an instrument for autonomy, information sharing and self-management.

Now we extend Deibel´s definition to define that an environment can also be empowered if technology creates an intelligent context that autonomously decides on performing tasks and information sharing. While an empowered individual is more active and participant, the empowered environment is more effective and efficient.

This paper discusses the role of mobile devices as empowering devices for assisting people with disabilities, both in the individual and ecological levels.

Mobile devices represent a major force towards empowering people with disabilities, due to their characteristics of being portable, their multiple sensors and processing power. Customers buy mobile devices with built-in accessibility resources; together with an enormous set of applications, this device is a powerful tool for enhancing human abilities and removing barriers for those with disabilities.

We want to discuss the role of mobile devices in the context of assistive technology in empowered environments. This is not yet a reality, even though being the object of attention of many researches around the world. Because of that, there is not much experience to serve as basis for discussions, so we must build prototypes and work out from the experience with them to understand the role of mobile devices in empowered environments for people with disabilities.

We organize this discussion as follows. Given the definition of empowerment in the previous paragraphs, we present the concept of distributed user interfaces (DUIs) in Section 2. DUIs are building blocks for interaction design in the context of device ecosystems and in the perspective of an Internet-of-Things (IoT) environment. We characterize mobile devices and their role in this ecosystem.

In order to bring the discussion to the assistive technology arena, Section 3 is devoted to the specification of an application we developed with the purpose to support deaf and hearing-impaired (D&HI) students in an inclusive educational environment. The application runs on mobile devices, which serve as students´ empowerment tool in an empowered classroom environment. This proof-of-concept serves as a background for our discussion on empowerment of users and ecosystems, mobile technologies and DUIs.

Finally, in Section 4, we address some questions regarding the development of assistive technology under the light of empowerment concept: should an assistive application empower directly the impaired user or should it empower the context in which this user will perform tasks or, yet, is there a middle ground solution of empowering both the user and environment? What is the role of mobile devices in a DUI environment?

2. Distributed User Interfaces

Distributed interaction is today a natural phenomenon. A study of the use of information and communication technology by young users (from 10 to 18 y-o) organized by Bringué and Sábada[2] concluded that these users perform multitasking over devices, using television, games and Internet navigation simultaneously.

The emergence of a variety of connected devices – many of which are mobile - make up an infrastructure that encourages the natural growth of new interaction models. Computational devices tend to connect resources, rather than compete for the user attention. By working together, they make user interaction richer and more complex. Several authors addressed new communication models and new human-computer interaction demands[3,4,5,6] and the crossmedia concept[7,8,9,10,11].

As pervasive technology evolves into IoT and an ecology of devices become commonplace, new interaction paradigms become necessary. Leading this tendency, distributed user interfaces (DUIs) have been discussed deeply in a series of workshops since 2011[12,13,14]. Yet, the concept of a DUI is still under discussion, as we present in the next section.

2.1. Definition of DUI

Several authors attempted to define DUI, as we collect in the following sentences:

"Distributed user interfaces are a user interface that distributes its components among several interaction devices available in the environment" (Berglund and Baang[15]);

"Interfaces whose different parts can be distributed in time and space on different monitors, screens, and computing platform, depending on several expressing parameters" (Demeure et al [16]);

"DUI is a UI with the ability to distribute parts or whole of its components across multiple monitors, devices, platforms, displays and/or users" (Melchior et al [17]);

"Distributed User Interfaces (DUIs) enable end users to distribute in time and space any widget and piece of information across different contexts" (Sendín and López [18]);

"... UIs, that support any combination (>1) of different input and output Interaction Resources (IRs) to simultaneously interact with a single application" (Blumendorf et al [19]);

"A Distributed User Interface is a user interface with the ability to distribute part of its components, or all of them, across multiple screens, devices, platforms and users" (Fardoun et al [20]);

"A distributed user interface is a user interface whose components are distributed across one or more of the dimensions input, output, platform, space, and time" (Elmqvist [21]);

"The result of migrating a part or all the interface components of an existing user interface (distributed or not distributed) across multiple devices or platforms" (Villanueva et al [22]);

"Distributed User Interfaces (DUIs) can be distributed in at least three senses: across different physical locations, across different computers, and across different displays" (Nacenta[23]).

In our research, we adopt Elmqvist´s definition but we complement our view on DUIs from the other authors. From the work by Blumendorf et al [19] we identify the most important characteristics of DUIs: automatic device selection, sensitivity to user context, user control, information sharing, multimodal simultaneous usage. Cited authors also observe that DUIs are multi and cross-device, multi- and cross-modal, multi- and cross-user and multi- and cross-application. "Multi-" refers to UIs addressing more than one element per dimension (device, modality, user, application) and "cross-" means that one element can change dynamically – that is, in execution time.

DUI applications do not run on a single device. We could classify as DUI an application that runs in different devices using responsive design, but this is not the target idea. Instead, a DUI application distributes interaction in different devices, based on context. The distributed interaction design attributes the most suitable device to a given situation, the choice of which is based on characterizing *forces*: (1) the human task to be developed, and/or (2) the content characteristics, and/or (3) the place where the interaction must happen and/or (4) the collaboration that is requested by the situation and/or (5) several other context attributes.

Instead of a single device, DUI applications consider an ecology of devices – that is, devices that relate to each other, that can collaborate and/or compete, that co-exist in time and space.

2.2. DUI applications and the role of mobile devices

Being DUI a concept in evolution, several authors are dedicated to establishing the infrastructure for implementing DUIs like Melchior et al [17], Fröberg et al [24] and ourselves[25].

Our research pointed that a few researchers are developing applications and proofs-of-concept that apply DUI concepts in order to understand better the distributed interaction phenomenon. A review of publications in the four editions of DUI workshops has shown applications in education, domotics, sketching, office collaboration and health care, but none of these has addressed assistive technologies. In spite of that, we consider that there is a huge potential for assistive technologies using DUI, because of its characteristics of supporting information sharing, promoting autonomy and allowing for self-management, which means empowering not only the individual but also the environment.

However, in the present, the actual ecosystem for DUI is rather limited. Many authors restrict the set of devices to smartphones, tablets and TVs, adding occasionally special-purpose sensing devices like running shoes and heart-

rate monitors. However, DUI concept is consistent with the concept of IoT, being the "face" of things when they need to interact with humans.

Thus, we understand that DUI applications have a good potential for task collaboration and public and private information management, being a candidate technology to support environmental empowerment.

The mobile device - which is the focus device in this paper - is the individual´s communication port to other participants and to the environment. It plays the role of the personal gadget – it is the close-to-the-eye screen, close-to-the ear loudspeaker. In a DUI ecosystem, mobile devices display information as other devices can do (PCs, TVs) but for personal use; it captures user input and collect information from personal sensors (like heart beat and temperature) as well as next-to-the-person context (geographic locale, position).

3. SESSAI

SESSAI is the Portuguese acronym for Supporting Deaf Students in Inclusive Classrooms. This application was developed as an assistive technology in our research group for purposes other than this discussion; actually, it was meant to support the study of factors for technology acceptance by D&HI students.

Yet, the development effort raised several other research questions, and here we will use SESSAI as a proof-of-concept for discussing the relationship between empowerment and interaction distribution in assistive technologies. To make this discussion possible, we will present briefly SESSAI requirements and the given solution.

Our scenario is an inclusive mainstream school where D&HI students as well as hearing students learn together a regular curriculum. Instructors apply different pedagogical techniques for their students, from the more traditional lecture given by a teacher to group work, evaluations and practical studies in laboratories and field.

In real classroom situation, D&HI students are in disadvantage. Among the many barriers with which a D&HI student has to deal in regular classes, situations of many-to-many communication are a particular issue. Ordinary classroom situations engages more than one person simultaneously speaking or even contains multiple events calling for attention. The interpreter, herself, is an example of attention calling event. In such situations, D&HI students cannot capture the information completely, for they must focus their sight in one target conversation at a time. This multiple attention requests were studied by Cavender et al.[26]

Based on this study and on field research with D&HI students and their teachers, the following essential requirements were proposed to SESSAI:

- Essential requirement #1: SESSAI must capture all conversations in classroom. SESSAI must capture all speech, from everybody present in the classroom - students, teachers, monitors and interpreters, as well as sign language.
- Essential requirement #2: SESSAI must convert all speech it captures to text. Even though there are discussions on written language comprehension by D&HI students, text will be the basis for automatic conversion of oral language to sign language, when possible.
- Essential requirement #3: SESSAI must record converted texts. Students should be able to review recorded converted texts afterwards. Due to dynamics of classroom, it may not be possible for the D&HI students to read every talk. This function allows them to review texts later.
- Essential requirement #4: SESSAI must record timestamp and present text in chronological order. This function intends to preserve sequence of conversation.
- Essential requirement #5: Communication sources must be identified. In a classroom, people talk simultaneously, explaining content, asking questions or commenting the content being taught. Simultaneous sources of communication must be distinguished so that the D&HI student can identify who is speaking or calling her attention.

SESSAI specification included architecture-dependent functionality:

- Participants´identification must be automatic.
- If a participant´s device is not identified, a notification to connect must be issued;
- Speaker can edit his or her text before posting. In case the speech recognition fails, the user can correct the text before posting.

- Use native and universal resources as much as possible. Considering that the mobile device is a person´s possession, the system should work independent of users' platform.

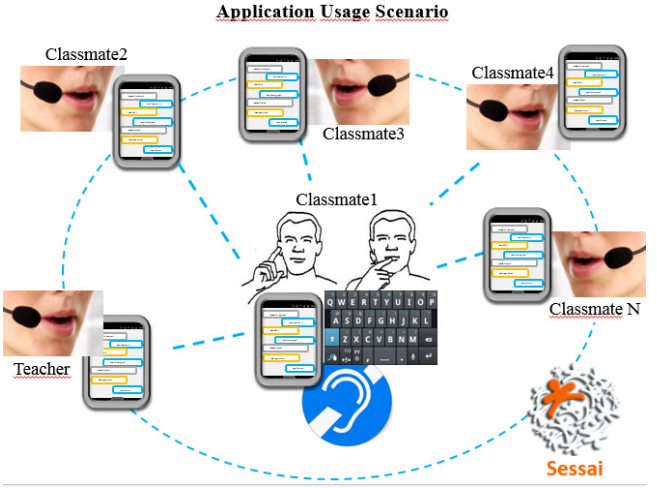

Fig. 1 SESSAI use scenario in a classroom, with multiple users.

SESSAI implementation looks like a group instant messaging system. In order to achieve these requirements and promote acceptance, SESSAI concept was inspired in technologies already available in the market for speech-to-text conversion, instant messaging and learning platforms.

Fig. 1 shows a usage scenario in a classroom where the students, D&HI or not, can speak and have their speech converted to text. Everyone´s mobile device shows all converted speech in a chronological order. In the ideal installation, the environment should be able to capture and identify each participant speech. However, because of difficulties in instrumenting the classroom, in our actual implementation each speaker had a microphone and a smartphone to capture sound and perform individual recognition.

SESSAI is a DUI application because it runs in an ecosystem of mobile devices, involving different users.

We invited users to use SESSAI in an inclusive school to understand acceptance factors. After the experience, we interviewed 11 deaf users. Seven users reported their desire to download the application to their own mobile phones, four of which expected they could carry that technology outside the target environment. The use of mobile devices was a key factor in acceptance. Four users declared that they would prefer to use the application only in the school environment.

4. A critical view of mobile device as assistive technology considering empowerment and distribution of interaction

Given this scenario, we recall the questions proposed in the paper introduction:

- Should an assistive application empower directly the impaired user, the context in which this user will perform tasks or is there a middle ground solution of empowering both the user and environment?
- What is the role of mobile devices in a DUI environment?

4.1. Which should be the focus of empowerment?

In our research, we performed a systematic literature review to find papers addressing user experience and acceptance of voice recognition applications designed as assistive technologies for D&HI people, especially those related to inclusive classrooms. We researched 9 bibliography repositories - ACM Digital Library, Scopus,

IEEEXplore, Citeseer, Engineering Village, SpringerLink, Web of Knowledge, HCI Bibliography, and JDSDE, looking for publications from 2003 and 2013, which resulted in 45 papers.

We examined these 45 papers to find whether the solution aimed the individual or the classroom. The analysis revealed that 28 papers addressed assistive technology for empowering the D&HI individual, while six addressed the empowerment of the classroom environment. Eight solutions empowered both individuals and classrooms. While more than half the papers show a choice for individual empowerment over 10 years of research, we cannot infer that this number justify empowering individuals as a best practice. In fact, empowering individuals may result in solutions that are easier to implement given present resources and knowledge. These solutions can be disseminated more easily and have the advantage of being portable, thus assisting users wherever they are.

Despite of that, researches about technological ecosystems, social networks and other collaboration resources are increasing in late years. One can expect that the advance of IoT technology may change the scenario, and more solutions that empower the environment may become popular in a short time.

There is one important philosophical argument toward empowering environments instead of, or as well as, individuals. If technology is with the user, he or she only will benefit from it. If it is in the environment, the advantage is shared.

Looking back to historical approaches to disabilities, we can recall the medical and the social approaches. Medical approach to disability considers that disabilities can be overcome with rehabilitation or assistive technology; in this point of view, disabled persons are thus outliers who must acquire resources to move toward the "normal" condition. This approach still underlies the design of several assistive technology devices and applications. Assistive technology is designed to return some lost ability to users who, by possessing the resource, can interact with the world as it is. In this case, we keep the environment *status quo*, the system entropy – and costs - low.

One example towards this argument are screen readers. Screen readers are user agents that capture the text equivalent in web sites and convert them to audio streams with text-to-speech technology, providing content accessibility for visual impaired people. Screen readers are placed in the disabled person´s device. They are suitably called a user agent technology.

Medical approach to disability is opposed by the social approach, which focus on individual differences and consequent disadvantages in the access to the world. In this approach, society produces barriers to disabled people, which should be removed and avoided by universal design. According to the Human Rights Council of the United Nations[27] "The focus is no longer on what is wrong with the person. Instead, disability is recognized as the consequence of the interaction of the individual with an environment that does not accommodate that individual's differences and limits or impedes the individual's participation in society". Such environments can be called as impaired environments, as opposed to impaired individuals, and can be classified as communication-impaired or physically-impaired environments, and so on.

Under this light, design of assistive technologies should give place to design of universal environments, accessible to everybody. Examples of works that elected this kind of approach are those by Cavender et al.[26] and Kushalnagar et al[28]. These authors designed solutions to minimize educational barriers for deaf or hearing impaired (D&HI) students in inclusive, instrumented classrooms.

4.2. What is the role of mobile devices in DUI environments?

We argued that mobile devices today are a personal gadget, which can run assistive applications and empower the individual that possesses it. In DUI applications, we find mobile devices as part of an ecosystem, playing the role of the closest device to the person.

Mobile devices in empowered environments are thus no longer a computational support where an assistive technology application can run; instead, it is one participant of this ecology, with some special characteristics, like an instrument in an orchestra. In empowered environments, we may have to change the name of this device from *mobile* to *proxy*, as the role in the distributed interaction is identifying the user and informing her communication preferences; capturing user context and informing context variables to the environment – location, speed, mood. When a blind person walks in an empowered urban environment, places, stairs, elevators, doors and other equipment dialog with the proxy device, which deploys the information according to user´s preferences. In an empowered classroom, a lecturer can have his gestures and movements described, at the same time his words are converted to

text and to sign language, everything being broadcast to everyone. A blind student proxy device captures the gesture description and ignore the sign language channel, while the dyslexic student proxy may capture all channels.

The important issue is not the architecture of the assistive technology but the displacement of concerns, from the individual to the environment.

5. Conclusions

In this paper, we argue that the role of mobile devices for disabled persons is moving from a personal gadget that runs assistive technology and accessible applications to that of a proxy to empowered environments. We argue that this change follows the evolution of the disability concept, from the medical approach that considers that disabilities should be "fixed" as much as possible to the social approach in which the environment should be adapted to support people diversity.

Our research agenda includes improving the SESSAI application towards a prototype of an educational environment, equipped with distributed interaction for supporting different disabilities.

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