Bringing down barriers: a method to include blind people in cooperative modeling

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***Abstract*—The inclusion of blind people in some math, computing, and engineering-related courses and jobs is challenging. Among the reasons for that is the frequent use of models that keep a strong dependence on graphical representations. Challenges are related not only to individual access and editing of such models, as well as to scenarios in which other sighted and blind people work cooperatively. The literature on cooperative modeling involving blind people is scarce and few studies have covered aspects related to coordination, communication, and awareness mechanisms in such activities. In this PhD project, we aim at proposing and validating a method to include blind people in cooperative modeling activities. To do that, we developed an accessible web-based tool, called Model2gether (available at model2gether.com), which can be customized regarding supported models, interface styles, and awareness mechanisms. Additionally, we have been conducting experiments involving blind and sighted people to identify: (i) the influence of blind's mental model; (ii) appropriate interface/interaction styles; as well as (iii) appropriate coordination, communication and awareness mechanisms in such activities. Currently, we are updating the tool, planning new experiments and considering the possibility of using haptic devices in a multimodal interaction style.**

***Keywords*— blind, cooperative, modeling, accessible, method**

I. Introduction

According to the World Health Organization [1], there are about 39 million blind people all around the world. The inclusion of people with this impairment in some computing-related courses and jobs is challenging. Among the reasons for that is the frequent use of models that keep a strong dependence on graphical representations [2], [3]. Examples of such models in the computing field are entity-relationship models [4], data flow models [5], and the UML - Unified Modeling Language models [6].

While the literature on the accessibility of these models, hereafter called graphical models, is extensive from the point of view of individual activities [7], [8], [9], [10], [11], [12], many activities carried on in academia and industry have a cooperative nature. Among these, we can cite:

- Teaching and learning: (i) when educators present graphical models and discuss with learners the features and deficiencies of these models; (ii) when educators construct or modify models with learners; (iii) when learners peer review activities based on models produced by classmates.
- Software development: (i) when teams hold meetings, workshops, and other activities aimed at analyzing and designing new systems; studying existing systems; incorporating new features, and performing maintenance.

The existence of solutions for individual activities does not guarantee the possibility of performing cooperative activities since there are several features of the latter that are not present in the former [13]. Among these features are: (i) communication mechanisms; (ii) coordination mechanisms; and (iii) awareness mechanisms [13].

The literature on cooperative modeling involving blind people is scarce [14], [15] and we have found only two software tools that support such modeling activities [16], [14], [17]. One of the tools implements coordination mechanisms using locks (when someone is editing an element, others cannot do it), but does not implement any communication or awareness mechanism. In a user study [14] conducted with 3 visually impaired and 3 sighted people, participants reported difficulties in understanding what others were doing in the tool, an awareness-related issue. At the other hand, a recent user study we conducted showed that continuous feedback is harmful to blind people in cooperative modeling. Moments of interruption as well as configuring the level of awareness were considered essential by blind participants. The other one supports the inclusion of blind people in brainstorming sessions. The system allows blind users to access both 'artifact level' and 'non-verbal level' information through a Braille display.

In this context, further research in this area is essential to gather more information and to produce technologies to support the inclusion of blind people in cooperative modeling.

II. Background

In addition to accessing and updating an artifact (model), there are three main types of social mechanisms that arise in cooperative modeling activities [13]:

- Communication mechanisms: to facilitate the flow of speech and to help overcome breakdowns along it;
- Coordination mechanisms: to allow people to work together and interact;
- Awareness mechanisms: to find out what is happening, what others are doing and, additionally, to let others know what you are doing.

Communication mechanisms involve both verbal and non-verbal communication. The latter includes deictic gestures, such as pointing to a model element and nodding to agree with someone else.

Regarding coordination mechanisms, one can establish a classification into two categories: master-slave and master-master [18]. In the former, one of the participants takes the activity control, while in the latter participants share the activity control. An example of activity in which coordination occurs is building graphical models in lectures.

In the case of a master-master coordination, it is important to define the editing possibilities of each member. One possible strategy involves maintaining a shared cursor among the participants. Thus, when considering graphical models, only one element of the model can be edited at once. Another potential strategy involves allowing each participant to freely change the model elements. In this case, it may be difficult to implement awareness mechanisms for the visually impaired, because the volume of information available about the changes is huge. In addition, the communication of this information competes with the communication of those related to the changes produced by the participants themselves.

Furthermore, it is possible to establish locks at different levels, to prevent two or more participants from editing the same element. Although the master-master coordination is possible in activities with graphical models, a master-slave scenario where there is a constant alternation between the roles of participants is more common. As an example, when a member of a team (master) explains details about a model, others (slaves) follow the explanation. Then, if one of the other members need to make his/her contribution, he/she can take the role of master.

Awareness, in turn, is related to the knowledge about what is happening and what others are doing.

When blind individuals participate in such activities, all this information competes for two main channels: auditory and haptic.

III. Research Question

The research question we address in this project is how to include blind people in computer-supported cooperative modeling. With regard to the question, we chose to consider only blindness, as opposed to all visual impairment degrees, because people with low vision may access and edit graphical models in its original graphical form, as sighted people, with the help of adequate tools (e.g. screen magnifiers and contrast adjusters). Additionally, the teaching and learning process and the software development process are the two contexts of interest in this project in which cooperative modeling takes place.

IV. Research Objectives

Considering the aforementioned context, the main objective of this project is the development and validation of a method for the inclusion of blind people in cooperative modeling. The method will specify a set of principles and activities that must be followed to choose appropriate interface/interaction styles, as well as coordination, communication, and awareness mechanisms. We will consider initially two types of graph-based models: UML (Unified Modeling Language) Use Case and Class models. To support the experiments and validate the method, we developed an inclusive web-based software tool, called Model2gether (www.model2gether.com) [19], [20].

The specific objectives of this project are:

- Identify the main factors that influence that type of cooperative work;
- Verify what interface/interaction styles as well as coordination, communication, and awareness mechanisms can be used in this work;
- Define what data about the participants and about the activity context must be gathered to choose the adequate interface/interaction styles;
- Describe how these data can be gathered;
- Define how to use this data to produce a specification of suitable interface/interaction styles, as well as of appropriate coordination, communication, and awareness mechanisms;
- Describe how to map this specification into supportive software systems requirements.

V. Related Work

Winberg and Bowers [15] examined the cooperation between sighted and visually impaired people while playing Hanoi Towers games. The authors emphasized the importance of providing visually impaired participants with a continuous feedback on the game state (awereness). Not maintaining a shared cursor control among participants was also identified as a factor that improves orientation, involvement and coordination of shared activities [21].

Oliveira et al. [22] discussed how visually impaired learners may interact with educators and with graphical content during Geometry and Trigonometry classes. The authors adressed how to translate deictic gestures made on a whiteboard with static content into a haptic representation.

Metatla et al. [16], [23], [14] proposed a tool, known as CCMi, which allows collaborative editing of graph-based graphical models for sighted and visually impaired people. The tool was developed in Java and allows the visually impaired to interact with the diagram via keyboard and an haptic device (Geomatic Touch[1]). The model is represented in two ways: in its original state (no changes) and hierarchically. The authors implemented concurrent access to models by locking means. Aside from this, no other mechanism to regulate the cooperation was implemented.

Kunz et al. [24] described a system (CoME) that supports the inclusion of blind people in brainstorming sessions. The authors' main contribution was related to investigating collaborative aspects in dynamic content. The system allows blind users to access both 'artifact level' and 'non-verbal level' information through a Braille display. Pölzer et al. [17] presented the users' opinions about studies conducted in trios (2 sighted and 1 blind participant) with CoME. The studies

[1] Formely known as Phantom Omni.

aimed at collaboratively creating mind maps. Both artifact and non-verbal communication were established. Leap Motion was used to detect deictic pointing gestures. A tree-view of the mind map was presented to the blind and Braille displays were used in the tests. Although speech output could be used with the developed interface, the authors tested only Braille displays.

Casela [25] studied the accessibility of data flow diagrams to blind individuals.

Regarding our previous published work in this field, we defined a set of high level user requirements to include blind people in cooperative e-learning activities in [26], [27]. Furthermore, we conducted a user study with 4 blind people to evaluate different awareness strategies.

VI. Method

The method described in this section was approved by the USP Universitary Hospital Research Ethics Committee (CAAE 49264815.3.0000.0076).

We initially conducted two systematic reviews. One of them on the accessibility of UML models to visually impaired people and another one on computer-supported cooperative work involving people with this type of disability.

Then, we defined the requirements and developed a web-based tool, Model2gether, to support experiments with cooperative modeling.

Model2gether's accessibility was checked through its conformance with WCAG 2.0. To do that, we used an automatic free service available at achecker.ca. No known problems nor likely problems were found by the service.

After that, we carried out a user study with 4 blind and 1 sighted people. The blind participants were invited from the Brazilian Blind Programmers List. The sighted participant was one of the authors.

Firstly, we invited the blind participants to test the tool in order to assure its accessibility. For this, they were asked to conduct the following activities: (i) open the tool website and create an account; (ii) sign-in into the system; (iii) localize the help menu, open and read it; (iv) open a use case model that was shared with them and identify the actors, use cases, and relationships; (v) create a new use case model based on a textual description; and finally (vi) share this diagram.

Before the tests, a lecture about use case modeling was provided by the sighted participant. Participants were allowed to make questions anytime. The lecture was used to assure that all participants shared the same definition about concepts that could influence cooperative modeling.

To perform the activities, each pair received 3 system descriptions to model using use cases (academic, restaurant, and e-commerce). The descriptions defined features so as to guarantee/ensure that the systems model size would not differ. Each model domain was explained to the partner. The features were divided (50/50) among the participants and each one had to create the actors, use cases, and relationships related to the features received. Some of the features overlapped in terms of actors and use cases in order to require participants' knowledge about what the other participant was doing (awareness).

In order to isolate the effects of awareness and non-verbal communication, each system was modeled with the same cooperative configuration (despite differences in awareness and non-verbal communication). Additionally, to assure that the order in which each awareness and non-verbal communication configuration was used did not influence the results, we varied the order for the users.

One of the systems was modeled without continuous information (A). The blind users were instructed to disable the checkbox "Follow model updates" and to turn it on only when they felt necessary.

Another one was modeled only with beep to inform that something changed or an element was selected (B). That is to say, no messages were continuously communicated about changes. Only a beep sound was reproduced when the other participant made changes to the model. To be aware about changes, the blind participant could navigate through the history of actions made by the other participant.

Finally, the last system was modeled with continuous awareness and pointing information (C). In other words, every change made to the model by one participant and every pointing was immediately communicated by the system to the other in the pair by messages, such as "A new actor was created: Student".

In the next step of the research, we are going to conduct experiments involving blind people to gather information that can help us reaching the project objectives. The experiments will involve the execution of a set of activities, further described. After performing the activities, participants will answer questions related to each of them. Blind participants will be asked to verbalize what they are doing during the experiments. Activities will be conducted both individually and in groups. They may be organized into five categories: model creation, peer-review, features addition, error correction, and refactoring. These categories are described next:

- Model creation: the participants will create a model from scratch.
- Peer-review: the participants will review the model created by others.
- Features addition: In this category, participants will be presented a valid model and will have to add new features to it.
- Error Correction: In this category, a model with errors will be presented to participants and they should identify and correct them;
- Refactoring: In this category, a valid model will be presented to participants and they should propose changes in its structure to improve its quality;

These categories involve common activities both in academic and industrial settings. They were organized in such a way that participants face a growing complexity. To be able to add features to a model, for example, he/she must be able to understand a model (peer-review) and create a model.

Different coordination, communication, and awareness mechanisms will be used. Additionally, we are going to test various interface/interaction styles.

All users will use a screen recording software to record their activity and the conversation will also be recorded with their consenting. Based on the participants feedback, we will iteratively improve the method (first version to be proposed) and the supportive tool (Model2gether).

VII. To Date Results

A. Publications and Submissions

The systematic review results were submitted to CHI 2016. The Model2gether requirements and a comparison with existing tools were published in RBIE [26] and SBIE 2014 [27]. Details about the tool implementation were published in CBSoft 2016 [19] and SBIE 2016 [20]. With regards to the conducted experiments, the results were submitted to CHI 2016. This PhD research project was presented at the ASSETS 2016 Doctoral Consortium.

B. Model2gether

As a technological result of this PhD, we have developed a web-based tool to support cooperative modeling involving blind people. It is a free software - distributed under the GNU General Public License (GPL). It currently allows cooperative modeling of UML use case models, but we have been working on extensions to Class and Entity-Relationship models.

C. Use Study

All blind participants were very excited with the lecture and the tool and gave positive feedback (e.g. "It was the first time I felt comfortable following a class that contains graphical content"). One of them used the tool a week later to work together with colleagues in order to create a use case model for a course he was taking.

VIII. Contributions

We have not found in the literature any method similar to the one proposed in this work. Additionally, no other tool was found with the same features as Model2gether.

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