Alternative Concepts for Accessible Virtual Classrooms for Blind Users

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Abstract—**The use of virtual classrooms by blind users is hindered e.g. by inaccessible user interfaces, graphical and dynamical content, as well as synchronous communication. Based on a requirements catalogue for accessible virtual classrooms and existing concepts to eliminate barriers for blind learners, alternative concepts are presented for a two-dimensional Braille display. An evaluation using tactile paper prototyping indicates an improvement towards accessibility and equal usage for all participants.**

Keywords-Tactile interfaces, accessibility, blind, virtual classroom, human computer interaction, tactile graphics display

I. Introduction

Blind users access a computer using screen readers and Braille lines. The output of these assistive technologies is text- and line-based. Graphical information can generally be perceived using alternative descriptions or tactile prints. Tactile graphics displays, like the *BrailleDis* [18], offer the possibility to display multiple lines of Braille text, simple graphics or diagrams and allow interaction via touch input.

Virtual classrooms are e-learning applications, which allow learners to interact synchronously over the Internet e.g. using text chat, audio and video conference and dynamic whiteboard. Software developers strive to make their virtual classrooms accessible e.g. by providing keyboard shortcuts, screen reader support, session recordings, closed captions and activity protocols. Previous research showed that *Blackboard Collaborate*[1] and *Talking Communities*[2] are the most accessible classrooms of overall 16 virtual classrooms analyzed [10]. Nevertheless, even if they were technically fully accessible via assistive technologies, issues concerning their dynamic, synchronous, interactive and visual character still pose barriers for blind learners [7,10]. The possibility to display simple graphics and to provide an insight on spatial layout and relationships on tactile graphical displays – like suggested in [14] – could help to improve the information retrieval, communication and collaboration in virtual classrooms for blind learners.

The research presented combines existing accessibility concepts for virtual classrooms and for non-visual two-dimensional haptic interaction in general with new approaches aiming at fulfilling a requirements catalogue [8] for accessible virtual classrooms. The requirements catalogue combines various guidelines for accessibility in general and accessible learning environments[3] and completes them with additional requirements derived from previous analyses [9]. This paper presents new alternative concepts for the *BrailleDis* in order to facilitate the participation of blind learners and summarizes their evaluation.

II. Related Work

A questionnaire conducted with blind and visually impaired learners [7] shows that synchronous collaborative communication tools are seldom used. Face-to-face communication is more common in education. Research aiming at accessible collaborative platforms include e.g. a whiteboard, which integrates a human translator [4], a wiki-based system offering an accessible WYSIWYG editor [12] or developments towards an accessible whiteboard with accessible basic interaction possibilities [15].

A. Concepts for the BrailleDis

User requirements for two-dimensional tactile representations need to be considered when designing user interfaces (UI) for blind persons. Similar to visual focuses, tactile or acoustic clues can help to guide users through the mapped information. For a facilitated orientation, frequently needed information should be displayed in fixed locations. Short distances between related information allow for a quick access to information and goal-oriented work [16].

In the project *HyperBraille*, a two-dimensional Braille display with 60 × 120 pins, the *BrailleDis* [18], and a software – the *HyperReader* for filtering the desktop and applications to be displayed on this device – were developed. For the display of UI, a tactile windowing system was designed, taking into consideration the requirements for two-dimensional tactile representations [16]. The windowing system divides the display into braille regions for different sorts of information [14,16]. These regions are, amongst others, the header region for holding window title information or a menu path, the body region displaying the content of the application and detail region for screen reader output or information about the focused element (see Fig. 1).

For displaying and manipulating graphical elements on the *BrailleDis*, there are diverse approaches e.g. for collaborative drawings [2], tactile maps [6] and mathematical curves

[1] http://www.blackboard.com/Platforms/Collaborate/Overview.aspx
[2] http://www.talkingcommunities.com/

[3] The considered guidelines comprise WCAG, UAAG, IMS Guidelines for Developing Accessible Learning Applications and ISO 9241-110.

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[3]. The findings of their evaluations provide a basis on best practices for UI layout and interaction techniques, such as a function to follow a users' focus [2], blinking pins to draw attention [6] or improved understanding using a combination of tactile representations with textual descriptions [3].

B. *Accessibility Features of Virtual Classrooms*

Basic accessibility features of virtual classrooms include e.g. keyboard support with sensible tab order and shortcuts, audio notifications and screen reader compatibility. Some virtual classrooms offer additional functionality, e.g.:

- An activity window documents the events of a session including timestamps [1]. The types of events displayed can be defined through filters. A command line can be used to perform actions such as posting a chat message or muting the microphone.
- Closed captions allow all users to provide alternative descriptions to displayed content [1,17].
- Accessible recordings allow repeating a session in one's own speed [1].
- Configuration of audible notifications or hot keys allows to adapt the UI to the user's needs and to increase the compatibility with assistive technologies [1,17].

C. *Mobile Versions of Virtual Classrooms*

For most of the leading virtual classrooms, a version for mobile phones is available. Due to a smaller screen size and possibly slow Internet connection, the functionality is often reduced to the basic features such as chat, audio conference, participants' list and presentation panel. Editing the whiteboard and using video conference functionality is usually not included. In most cases, the only role available is "participant", concentrating on perception rather than interaction.

The layout of these mobile versions is interesting for the alternative concepts presented in this paper, as the smaller screens require information reduction – even though the resolution is still much higher than on the *BrailleDis*. However, the concepts for the *BrailleDis* aim at facilitating interaction with the goal of equal participation for blind learners. Thus, no functionality was excluded in the concepts presented. *Adobe Connect Mobile*[4], for example, uses tabs and buttons on the left and right side of the content region to switch between panels (chat, whiteboard, video conference, participants' list) and to display status information (microphone muted, video activated etc.) (see Fig. 1).

III. Alternative Concepts

In the following, alternative concepts are presented with the goal to improve the accessibility of virtual classrooms for blind participants by eliminating barriers and respecting the requirements catalogue developed.

A. *General User Interface*

Eurobraille (2×4 pins for a letter) is used for the display of text. In UI elements, a small letter is used due to economic layout and thus only 2×3 pins are necessary. To avoid confusion, the labeling needs to be discussed in the user manual. The general layout of the tactile UI is based on the structure of the regions of the *HyperReader* using header, content (body) and detail region, combined with the layout of the UI of virtual classrooms on mobile devices (see Fig. 1). Lines are used to separate regions, and tactile icons (tactons) were developed and evaluated. The focus is represented by a vertical line, the caret by points 7 and 8 of a Braille letter, emphasized via blinking pins (see Fig. 2).

1) *Header Region*

The header region is derived from the *HyperReader* concept. It displays the virtual classroom's name and focused panel or functionality.

2) *Content Region*

The content region is similar to the *HyperReader*'s body region in respect to the content, which is displayed in this area. The type of information displayed depends on the tab selected in the panel region. Not all information available on the graphical UI is displayed simultaneously, but the presented content is reduced to one functionality (chat, whiteboard, participants' list etc.) of the virtual classroom, similar to the layout of *Adobe Connect Mobile*.

3) *Panel Region*

The panel region contains tabs for the main functionality of the virtual classroom – activity window (*a*) as an overview, whiteboard (*w*), chat (*c*), participants (*p*) – as well as settings (*s*). Depending on the selected tab, the respective information is displayed in the content region. The selected tab is indicated by removing its right border. The initials of the tab's names are used as labels. A number next to the tabs *a*, *w*, and *p* indicates the amount of new events for this tab.

4) *Status Region*

On the right of the content region, status buttons indicate (de-)activated functionality or available information for a focused element. A surrounding rectangle indicates activated functionality; a bracket indicates deactivated functionality. The microphone (*m*) button can be used to mute or unmute one's microphone. The hand (*h*) button can be used to raise or lower the one's hand and to indicate the current status. A single click gesture changes the state of follow (*f*), microphone (*m*), video (*v*) and hand (*h*). A single click on *b* creates a bookmark with default title. A double-click on *v*, *d* (description), *l* (link) or *b* opens a respective view in the content region, allowing to add or change video settings, description, links or bookmarks (see Fig. 3 and Section III.B).

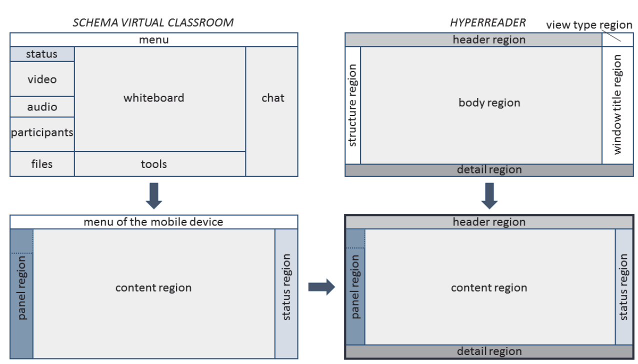

Figure 1. Layout schemas of virtual classrooms, *Adobe Connect Mobile* and *HyperReader,* deduced to the presented alternative concept.

[4] http://www.adobe.com/de/products/adobeconnect/feature-details/adobe-connectmobile.html

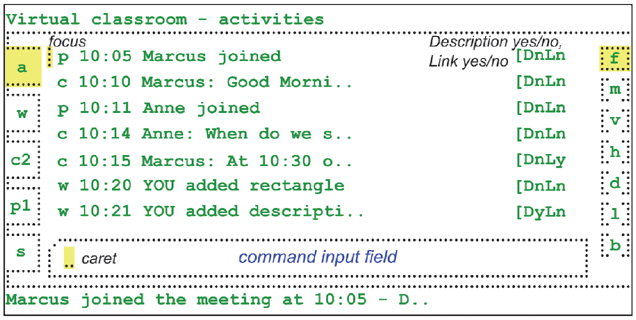

Figure 2. Mockup *activity window*. For better readability, Braille was replaced by normal print.

5) Detail Region

The screen reader output and detail information to the focused elements is displayed in the detail region.

B. Development of Alternative Concepts

The following section presents the most important alternative concepts for improving the accessibility of virtual classrooms for blind users.

1) Activity Window

The concept of the activity window of *Blackboard Collaborate* was adapted for the tactile UI (see Fig. 2). Events and activities – such as chat messages, changes of the participant's status and new content – are listed including a timestamp. Depending on the type of event, further information is listed, such as the participants involved or links to the corresponding element. It is possible to filter the events to be displayed. Simple commands – post a chat message, raise hand etc. – can be entered via a command input field.

2) Whiteboard

Drawing on the whiteboard using the keyboard is not supported by the virtual classrooms analyzed in [10]. Therefor, the use of vector graphics for the whiteboard is an important prerequisite. In the concept presented (see Fig. 3), the tools available for the whiteboard (*w*) are reduced to basic geometric shapes, text and manipulation tools which can be selected via keyboard or a click gesture. Drawing of elements on the whiteboard is possible by defining start and end point. The properties are displayed in the *detail region*.

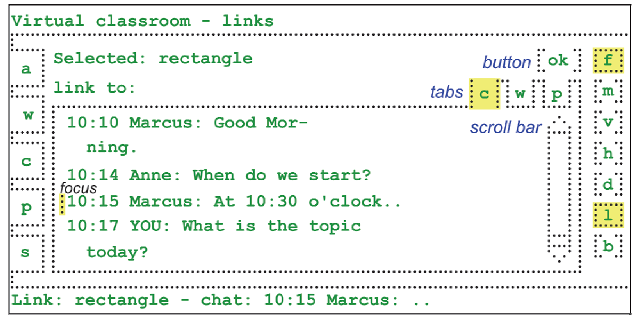

Figure 4. Mockup *links*. For better readability, Braille was replaced by normal print.

3) Follow Functionality

With the follow (*f*) button activated, the participant follows the live events of the virtual classroom. This includes automatic changes of the interface, e.g. a shift of the position of chat messages as new messages are posted or a switch to the next slide of a presentation. If *follow* is deactivated, the participant freezes the synchronous meeting in order to perceive the information at his/her own speed. In such a 'frozen' meeting, the learner has the right to navigate between slides and content at wish. As the live session does not pause, reactivating the *follow* button is comparable to reentering a classroom after taking a break. This function might be useful in phases of idle time e.g. to catch up on missed content.

4) Video

Even though video is not perceivable for blind users, it is important for social presence and the facilitation of equal operation. Thus, this concept provides a mechanism for assisting with the image selection. Besides the possibility of (de-)activating one's video transmission in the status region by double-clicking on the button, the participant can test the transmission. The user receives auditory instructions to move the camera until his/her picture is centered in the video. On the *BrailleDis*, the learner can check if the own picture is congruent with a default shape in terms of position and size.

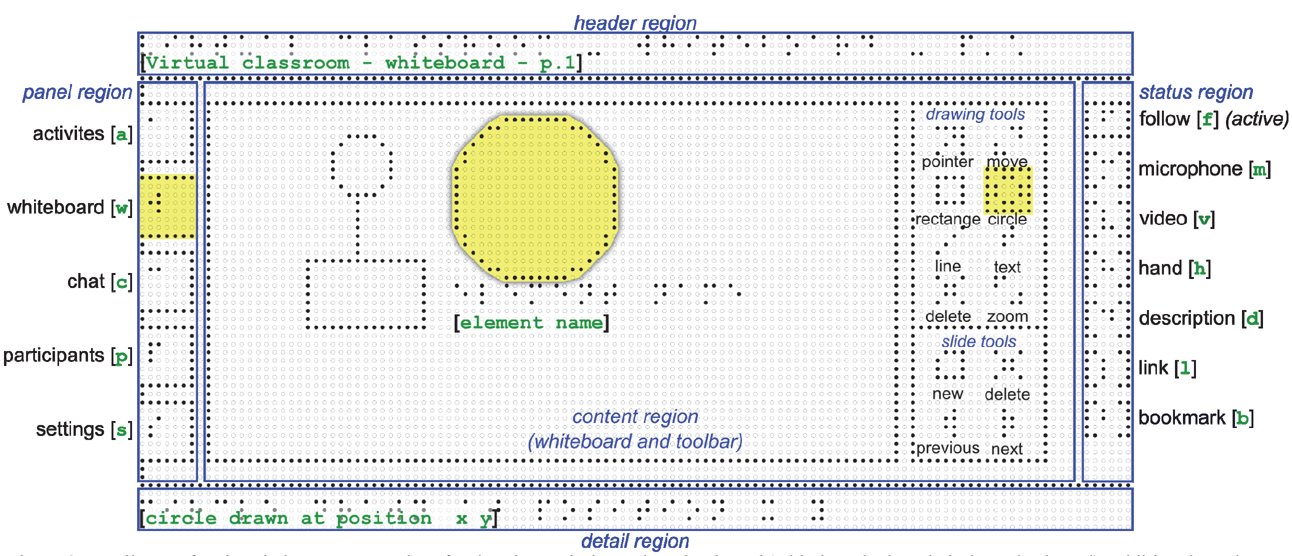

Figure 3. Tactile UI of a virtual classroom. Mockup for drawing a circle on the *whiteboard* (whiteboard tab and circle tool selected), additional mockup element as an overlay for the recently drawn circle. Black dots: set pins; white circles: lowered pins; blue: region names; green: Braille translations; black: explanations/widget functionality; yellow: selected/active elements.

5) Descriptions

Descriptions (*d*) for content elements can be added and edited by every participant similar to the closed captions functionality of existing virtual classrooms. They can serve as alternatives for non-text elements or further explanations. This feature can also be helpful for non-disabled students, e.g. for collaborative note taking or annotations. If a description is available for a focused element, it is indicated by a frame enclosing the description button in the status panel.

In order to edit a description for a focused element, the user double-clicks on the tacton (*d*). Element name and input fields for title and description are displayed in the presentation panel. The input is confirmed with the button *change*.

6) Links

A new concept in virtual classrooms to facilitate orientation and the recognition of semantically related elements is the possibility to use links (*l*) (see Fig. 4). A chat message, for example, can be linked to a whiteboard element in order to connect a question to its subject. The user selects a content element and performs a double-click on the link button. In the content region, the link view is displayed. Element types to which can be linked to are grouped in tabs according to their type. The user selects the appropriate tab and the desired element and confirms with the *ok* button.

7) Bookmarks

After a live session, a participant might want to repeat certain passages, which could not be perceived fast enough. For key events, such as a slide change, bookmarks are set automatically. Additionally, the participant has the possibility set his/her own bookmarks at any time. Either the title information is set by default or the participant enters title and description – e.g. a need for clarification – for each bookmark. The bookmarks serve as jump labels in the recording and are displayed in the activity window.

8) Recordings

In order to repeat the collaborative session at one's own speed, a recording of the meetings is possible in almost every virtual classroom. Unfortunately, the saved content is often only available in a pixel-based format. In order to allow screen readers to access the information, textual and vector information need to be maintained and temporal controls have to be available via keyboard. The availability of activity protocols, bookmarks, descriptions and links increases the benefit of such recordings for blind and sighted learners.

IV. Evaluation

The goal of this evaluation in an early design stage is to recognize potential problems in terms of alternative concepts and UI design before the implementation.

A. Methodology

Tactile paper prototyping [13] was used to evaluate the usability of the alternative concepts. Instead of presenting and designing mockups with pen and paper, the UI is designed by using predefined tactile UI elements in form of embossed Braille prints (see circle on whiteboard in Fig. 3).

The evaluation was conducted with one subject at a time and one conductor, who explained the tasks and simulated the events of the interface (change of views, screen reader output etc.). The evaluation was documented by using audio recordings and a video of the subject's hands.

The evaluation commenced with a questionnaire about the subject, the computer literacy and his/her previous knowledge of e-learning and virtual classrooms. It concluded with a questionnaire on the tested concepts. After a short introduction to the UI elements for the tactile representation of the virtual classroom, the subjects were asked to place the elements on a frame, the same size as the *BrailleDis*, as they would prefer their placement on a tactile Braille display, similar to a puzzle. Successively, the basic layout was presented by the conductor. The second part of the evaluation consisted of the presentation of different tactile interface views and the simulation of typical working techniques, e.g. posting a chat message or drawing an element on the whiteboard. The subjects were asked to comment on the presented interaction techniques and to propose possible changes.

B. User Test

Six upper class students participated in the evaluation, five of them legally blind and one visually impaired. Almost 20 true to scale paper mockups were presented with additional mockups for single UI elements. Due to similar UI views and designs and a reasonable test duration, each subject could only evaluate a selection of mockups. Thus, two main paths to choose from were defined: (1) activity window – chat – links and (2) activity window – whiteboard – descriptions[5]. In case time remained, bookmarks or tactons were evaluated. Some subjects evaluated further mockups on their own demand. The views for whiteboard and chat consisted of multiple mockups, which were placed on top of each other in order to simulate interface changes and interaction. The views for participants' list and settings were not included in the evaluation, as these views do not contain new concepts or interaction techniques.

C. Results

The basic interface layouts created by the participants were similar to the one used for the mockups. The primary deviation was in the placement of panel and status region as some preferred a horizontal orientation next to the header and detail region. The content region was always placed in the center of the display area. The subjects did not use available lines of set pins as separators due to distinct borders of the paper elements. Altogether, the basic layout seemed to accord to the subject's expectations. Overall, the subjects approved of the concepts presented and considered their tactile representation on the *BrailleDis* and their functionality as

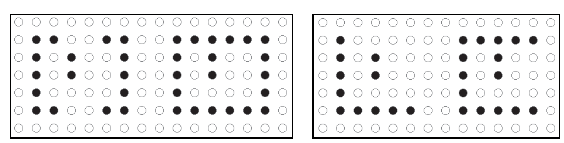

Figure 5. Tacton mockups with varying border styles (unselected/selected): present design (left) and suggested redesign (right).

[5] Number of evaluations of the different mockups: Activity: 6; chat: 4; whiteboard: 5; links: 3; descriptions: 3; bookmarks: 3, tactons: 2.

useful. The interaction techniques for drawing on the whiteboard or composing a chat message were assessed as logical and easy to use, even though initial training is required.

During the evaluation, one criticism was the lack of distance between the tacton borders and their labels, as this hinders the readability of the letters. Some subjects also asked for different border styles for marking a selected and unselected button (see Fig. 5). This shows a need for a redesign of the UI elements in the panel and status region as well as regular buttons.

V. Conclusion and Outlook

In this paper, alternative concepts for a tactile UI for accessible virtual classrooms for blind learners were presented. These concepts respect the requirements catalogue for virtual classrooms [8]. The personal needs and preferences of a learner consist of three categories: display, control and content [5]. The alternative concepts presented suggest adaptions in all three categories: the display and structure of information is adapted for the *BrailleDis*; the control corresponds to the user's needs and preferences as it supports assistive technologies and allows for personal settings, e.g. sounds or alerts. In terms of content, supplementary functions, such as descriptions and links, are proposed. The responsibility of alternative representations for visual media is with the authors of the content and not scope of the concepts developed.

The evaluation confirms the overall usability of the concepts. The positive findings of the evaluation might have been influenced by the inexperience of the subjects concerning virtual classrooms and the *BrailleDis*. To clarify this effect, the evaluation needs to be extended with more experienced subjects.

Due to the high cost of the *BrailleDis* and limited availability of compatible software, one cannot presume a general usage of this assistive device. It is therefore sensible also to develop interaction techniques for regular Braille lines. However, other technologies for two-dimensional tactile graphics displays will presumably reach marketability in the next years so that concepts developed on the *BrailleDis* can be adapted for other displays.

Currently a revision of the alternative concepts and their implementation is taking place and further evaluation is planned. So far, the evaluation concentrated on the accessibility of the virtual classroom and usability of the UI. Further evaluations also have to focus on synchronous interaction with other participants in order to be able to determine the benefit of the concepts e.g. in terms of dynamic changes, social presence, communication and collaboration.

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