

# Accessibility support for information and interaction systems – conceptual and prototypical development of a nonlinear interaction modality for visually impaired people

Designing a white cane metaphor

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*A white cane for blind people should provide a way for visually impaired people to use interaction- and informational systems effectively and efficiently, where information possibly existing implicitly e.g. on a website may be identified and recognized as such. Actual web-reader-solutions provide a linearization of content. By using mental models of visually impaired they shall be able, with help of a nonlinear interaction-modality which is the metaphor of a white cane, to interact with interaction- and informational systems, increasing performance compared to contemporary solutions.*

KEYWORDS: Requirements Engineering, mental models, metaphors, conceptual models, acoustic feedback, tablet mapping, prototyping

## 1 Introduction

### 1.1 Motivation

Nowadays visually impaired people interacting with a computer system don't get the same access to *information* as everyone else. Through several barriers which exist<sup>1</sup> when interacting with information and interaction systems they are being forced to use and *per-*

*ceive* this information in a *linear* way. There is a loss of information taking place due to the lack of a visual channel. But there is another loss of information through the *topological<sup>2</sup>* order of the information itself. If, on one hand, it would be possible to use this information to create or adapt mental models and, on the other hand, to use this knowledge to automate the process of information retrieval and/or create an efficient and effective way to access and manipulate this information this would mean a completely different approach to existing systems. Non-linearity, a more free and intuitive

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<sup>1</sup> Namely these are the pixel-, the mouse-, the graphics-and the layout-barrier, see also Boecker[3], Boyd[4]

<sup>2</sup> topology: by this term we describe the spatial distribution of objects in a space

way to access, select, create or manipulate information would be the benefits of such a system. The idea is to use an input device like a graphics tablet and a pen, to get a topological-related navigation scheme. The tablet itself is an aid which implicitly and explicitly marks the boundaries of the screen and maps elements (e.g. text, graphic, spreadsheet, etc.) which may be active within these boundaries. This work focuses primary on visual impaired people who don't have any or very little visual knowledge with informational and interaction systems. As tests show, there does exist a spatial knowledge in blind children according to Landau et al[6]. So if it is possible to combine that knowledge with mental models in order to map this with topological information a new way for blind people to access information system could be created.

## **1.2 Definitions**

### **1.2.1 Accessibility**

Accessibility is used to describe the degree at which a system may be used by people where the system may not have any technical nor physical barriers.

### **1.2.2 Mental Models**

Johnson-Laird describes mental models as either analogical representations or a combination of analogical and propositional representations of the world they are interacting with. They are distinct from but related to images. A mental model represents the relative position of a set of objects in an analogical manner that parallels the structure of the state of objects in the world.<sup>3</sup>

### **1.2.3 Metaphors**

A metaphor is defined e.g. as a visual conception of an abstract concept. This means we must analyze with a system for visual impaired people whether there is something like a graphical association and a formation of synonyms with concepts of the real world.

### **1.2.4. Conceptual Models**

Conceptual models focus on the way how systems are understood (with existing mental models) by users, designers and external factors. This helps designers to develop appropriate mental models of the system. While the seven stages model (Norman) points towards interfaces under consideration of the cognitive processes, the user-model of Herzeg[5] maps actions on seven levels, while each level depends on talents, rules or explicit knowledge (based on Rasmussen's model). The individual levels shall supply mechanisms, which minimize communication and interaction errors. Relations to knowledge have to be found, whether this is on the semantic, the pragmatism or on the sensorimotorical level, where learned operations can be automated.

### **1.2.5 Fitts' Law**

The larger the distance between source and destination, the more time we need to reach it (e.g. with a mouse) and the larger the diameter of the target in relation to the distance the fewer time we need to reach it. This directly affects the design of software products, since e.g. Buttons, which are larger can be reached faster according to Fitts' Law. An important realization is that objects are more easily attainable in the area of the display corner/boundaries, since the pointer remains in these areas.

### **1.2.6 Hick's Law**

Hick's Law describes the time it takes to search a selection of n possible targets. There are coefficients which depend on the device and the knowledge of the user. E.g. Hick's Law can be used to show that hierarchical menus have disadvantages over non-hierarchical menus. That's one reason why pie menus are being taken into consideration within the white cane system.

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<sup>3</sup> For more information see Sasse[8]

## 2 Requirements Engineering

### 2.1 Information gathering techniques

Early in the development process it is necessary to gather the Requirements of the system to develop. Since this is user centered design there have to be used techniques which highly involve the user as part of the design process. This can be achieved by various techniques, such as interviews, think aloud, and so on, depending on the state of the design process. In a very early state, with probably no system available a low-cost evaluation method is the cognitive walk-through according to Landau et al.[7], which allows to assess the usability of a system early in the design process. By simulating the interaction between user and the system through a cognitive process it is possible to discover usability problems by answering a series of questions. We used this technique within this work and gathered more information by interviewing visually impaired people.<sup>4</sup>

### 2.2 Requirements

Here are some of the results of the Requirements Engineering which form a base of a first prescriptive model:

#### 2.2.1 Functional Requirements

Not too many sound sources have to be played (a maximum of three) at the same time, only using different frequencies. Then, the learn-ability of the system should be improved by using aids, such as a help program or a tutorial area. There needs to be acoustic feedback for all kind of events, re-orientation needs to be supported. Next to the auditive feedback a hardware device for haptical feedback for a more accurate positioning should be taken into consideration in order to allow mental models to be adapted. The systems paradigm relates on topological navigation, so it has to be possible to use a random point as a starting point. Shortcuts have to be reduced while basic functionality needs to be placed on the pointing device. An unwanted action has to be recogniz-

able and undo-able. Immediate feedback is indispensable. Input modalities which need full focus and attention must be distinct from other interaction elements

#### 2.2.2 Non-functional Requirements

Time is a critical factor. It is hard to improve effectivity and efficiency of other systems, especially because the topological approach consumes more time at first glance. Other advantages need to raise the acceptance of the system. Sounds visually impaired people are used to have to be implemented. Cognitive workload needs to be minimized and rerouted on the motor processor. There shouldn't be a parallel processing of cognitive and perceptual processors (like having to press a shortcut while pressing a button on the pointing device). Acoustic associations have to be supported. There needs to be an optimized relation of tablet/pointing device to keyboard regarding functionality and flexibility. This is essential since putting too many functions on the pointing device might lowers functionality while putting to many functions on the keyboard might get too complex and lowers usage of the topological approach. There needs to be a modality for advanced users to reach a point in a faster way. A synergy of given solutions shall provide the best result for merging the different metaphors and paradigms. The systems needs to reside in the background.

## 3 Prototyping

### 3.1 Prototyping techniques

To gain a focus on explicit problem areas within the system, prototypes allow different views on it. By using different prototyping techniques, such as requirements animation, rapid, incremental and computer based prototyping it is possible to achieve different aspects of the system. In the end a storyboard was used to communicate the handling within the system designer team, while a specialized prototype (for the target group) was created as a base for

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<sup>4</sup>Included were also the results of Augustin et al.[2]

further information which influences the prescriptive model.

### 3.1.1 Specialized Prototype

While using an acoustical navigation it is important to find out the optimal radius of a sound source, if every object needs to have its own radius (depending on its size), how many sounds with different loudness can be perceived and processed at the same time. Furthermore the first prototype measures time for objects with different sizes, relative positions etc. To obtain information the following components are part of the prototype:

different sound sources

gradual sound radius

fullscreen-mapping of the system

areas which signal the entrance and the exit into/out of an object

object recognition when pointing on an object

different sizes and hard recognizable objects

## 3.2 Prescriptive Model

Using the realizations of the prototypes and the requirements engineering and turning it into a first prescriptive model brings up the challenge to communicate complicate and/or abstract concepts both to the user but also to the system designers. Different specifications are pointed out to describe semantics and pragmatics as well as the relation of semantics with the syntax. Additionally the elements used in this model include affordances, which depending on the context may be functional, cognitive, sensorial or physical. To relate on technologies that worked satisfactorily and to get a sense of the interaction elements, the prescriptive model is oriented towards the Apple Human Interface Guidelines[1]. This includes the following elements:

input: the classical text selection using mouse or keyboard may not be sufficient for the white cane metaphor. Instead the lasso metaphor is being used for selecting a text, while for a refined selection the mapping method may be applied. Alternatively a combination of classical methods and lasso metaphor can be applied. Selecting spreadsheets is similar to text selection but uses extensively the mapping method to divide the spreadsheets into logical units. The same goes to graphics while there has to be differentiated between pixel and vector graphics.

drag and drop: The lasso metaphor is being extended for a double lasso metaphor which connects two operands with one action.

text: While defining the way text should be used doesn't make much sense since the system has to work with existing solutions there needs to be found a way to transform explicit and implicit information of the text itself. One approach is to use different voices and moods of a text-to-speech system to imply different font styles e.g. bold, italic. By adding modulated sounds color can be communicated, although this is limited to differentiating between bright and dark colors.

icons/hearcons<sup>5</sup> (Boecker[3]): The characteristic of icons being a metaphor for an object of the real world brings up problems matching them to a system for visually impaired people. Since these people use objects by touching, hearing or smelling items there is a barrier using them. So an object on a computer system may only be accessed by its specific sound, which may be reduced to meta information (like e.g. file size, file name). A solution comes up with the concept of hearcons, grouping objects into categories and turning them into characteristic sound sources which constantly give auditive feedback in relation to the cursor.

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<sup>5</sup> A hearcon consists of a sound volume, position in a room and an interaction area

cursor: The cursor acts as a visual feedback for many different situations. So for a white cane metaphor it is necessary to give permanent acoustic feedback, while the cursor itself is not visible and the system as a whole is responsible for appropriate feedback.

menus: Hierarchical menus with their linearity may collide with the non-linear white cane metaphor. In addition there is a loss of efficiency searching the way through the menu structure. A more efficient way due to its larger destinations area according to Fitts' Law is a pie menu (Don Hopkins)<sup>6</sup>, which completes the system with a non-linear way to navigate through menus.

windows: While windows provide a container for the content they should not get into the way while interacting with the system. By mapping their content automatically they are being put into the background so they won't disturb interaction with the content. Scrolling through the content is possible by gesture recognition, since depending on the number of elements it may be impossible to map the content as a whole.

The basic actions that need to be performed include modification, selection, focussing, information retrieval.

### 3.2.1 Lasso Metaphor

The lasso metaphor is based on the idea of capturing elements, like in real life. This metaphor is being used constantly throughout the model and is applied by surrounding the objects of interest with the input device (pen). It allows a one-action-movement to modify an operand (or even n operands) by just one action. As this concept is useful for a one operand action it also can be used, as described, for a two operand movement (like Drag and Drop). Since reducing the cognitive load has a high priority this action needs to be split into two

parts, since according to Fitts' Law this operation is less accurate than just pointing the mouse as it involves pointing *and* pressing a button. The lasso metaphor gets rid of this problem by attaching one operand directly to the first action. This can be done by double-using the lasso, which means that the object of interest has to be surrounded twice. This is part of the *drag* operation. The drop is being used by simply pointing on the destination (which in relation to the context gives an auditive feedback to the user) and pressing an action button to simply *drop* the object onto the context-container.

### 3.2.2 Mapping

Mapping means the concept of focusing an interaction object and placing its extension within the boundaries of the graphics tablet. This is done virtually by resetting the absolute position of the mouse but has the same effect as if the objects were zoomed onto the tablet. Due to the boundaries a very fast navigation to outer points (according to Fitts' Law) is possible. This can be used for navigation purposes as well as for gesture and position recognition which uses the boundaries for specific actions (e.g. scrolling).<sup>7</sup>

### 3.2.3 Structuring content

By structuring content within containers it is possible to group them as logical units. This provides the possibility to attach to each group a specific sound, namely a "hearcon", which provides acoustic feedback in relation to the cursor (compare to 3.1.1 Specialized Prototype). Within the tablets boundaries it is possible to memorize a position of any container to get a topological overview and/or to get a faster access the next time the object needs to be used. This can be improved by adding haptic feedback-elements to the tablet to support a better orientation. Containers are reduced considering Hick's Law, because the less containers exist the fewer time it takes the user to

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<sup>6</sup> for more information see <http://www.piemenus.com>

<sup>7</sup> For an improved way to implement gesture recognition see also Tandler[9]

choose an object. Containers can be mapped onto the tablet containing other containers or information which can be accessed by the described techniques.

## 4 Conclusion

Within this work important requirements were gathered as a base for a prescriptive model. This model has been specified by using existing and new techniques and metaphors. The research of the way visually impaired people interact with such systems and discovering if and how mental models develop through the white cane metaphor is critical for a successful implementation of this system.

Through the nonlinear approach within the white cane metaphor we assume a more efficient and effective way to interact with interaction and information systems. A secondary effect needs to be examined, as the information system might be used more and more effective and efficient as mental models develop. This is true for visual impaired people who don't have any visual knowledge but is also interesting for visual impaired people with visual knowledge as this target group may not need to learn the braille alphabet anymore. Both groups can profit by this system with no need for an expensive braille output device, so there should be a strong secondary effect of saving time and money, too.

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More references can be found within the bachelor thesis.