INTERACTION DESIGN FOR VISUALLY IMPAIRED STUDENTS: INITIAL FINDINGS

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ABSTRACT

This paper reports on the initial findings of a study on improving interaction design for visually impaired students.

Keywords

Interaction Design, Visual Impairment.

1. INTRODUCTION

Current interface design for teaching visually impaired students, even when SENDA (Special Educational Needs and Disabilities Act in mainland UK) or SENDO (Special Educational Needs and Disabilities Order in Northern Ireland) compliant, has often neglected the direct involvement of target users in determining the requirements specific for their needs. In particular, there is a lack of awareness of the cognitive issues for the spectrum of users deemed to be visually impaired. A research project funded by the Higher Education Academy aimed to determine and produce criteria for the design of interfaces through the participation of target users from the outset, implementing these criteria in teaching exemplars in computer science at Ulster, and in electronics at York. An important constraint was that these criteria would be inclusive; usable by both sighted and partially sighted students as well as those with other impairments. Furthermore, inclusive design should not impede those without impairments. This posed a considerable problem for both the exemplars at York for conveying electronic circuit diagrams and Ulster conveying Unified Modelling Language (UML) diagrams [3].

2. METHODOLOGY

The first activity required is knowledge acquisition. Different authors present methodologies with varying stages of knowledge acquisition, but fundamentally they all involve: the identification and conceptualisation of requirements and problem characteristics, formalising these into some mediating representation scheme, implementation, and final testing and validation [4]. Knowledge acquisition can be machine-aided or human-labour oriented.

Johnson and Johnson's methodology [7], enhanced by Graham [5], proposes a three-stage knowledge acquisition process based around semi-structured interviews. The first phase is to perform a broad, but shallow survey of the domain. This allows the elicitor to become oriented with the domain, so a more flexible approach can be taken. This type of horizon broadening is a standard approach in social science research. Once this shallow trawl of the domain has been done, the second phase requires that a more detailed task analysis is performed by the elicitor, focussing on the area of interest. The structure of the interview uses a teachback technique to traverse the domain and validate elicitor understanding with the result that the elicitor progressively refines the model of the expert's competence. This model is qualitatively drawn up and uses a mediating representation, Systemic Grammar Networks (SGNs) [2]. These are a context free, qualitative representation, which can be used as a tool for the systems design, but their use does not imply the final application of any particular knowledge engineering software or methodology. SGNs have been used in many domains including oncology, pcb (printed circuit board) design, and fault diagnosis. The third phase of this approach is to validate the models drawn up from the expert with the wider expert community. The theoretical predictions of the model are presented to the initial community used in the first phase, and then to a further independent population, to check the appropriateness and validity of the model which has been created.

This knowledge acquisition methodology was adopted and tailored to the needs of the project. The first phase, the Broad and Shallow Survey, was achieved by arranging local interviews with clients from the Royal National Institute for the Blind (RNIB) in London and in the University of Ulster, using questionnaires specifically tailored to suit visually impaired interviewees. The second phase, a more detailed task analysis, was achieved through the design of semi-structured interviews with a visually impaired student expert at Ulster. Knowledge synthesis and analysis of interview findings led to design criteria rather than the employment of SGNs which were not considered practical for visually impaired experts.

Validation (and verification) is to be achieved by the evaluation of implemented criteria in exemplars at Ulster and York, for teaching computer science and electronics respectively.

This paper reports on the first two phases of the knowledge acquisition.

3. RESULTS

The Broad and Shallow Survey conducted at Greenwich with the RNIB resulted in a great deal of relevant publications, materials and links to appropriate sites. Guidance on “Designing forms and Questionnaires” [10] was sent from the RNIB. It confirmed that the best option for knowledge acquisition was through semi-structured interviews or questionnaires, completed either face-to-face or over the telephone. This accommodated the resolution of any ambiguities by allowing the interviewer to clarify points, and to overcome on-line questionnaire fatigue. It also facilitated the knowledge acquisition to take place without the need for additional tools, such as those described below being required (Braille printers or text-to-speech output, etc).

Current interface design for partially sighted and blind users predominantly includes Tactile User Interfaces (TUIs) or Audio User Interfaces (AUIs) [1], [9]. The RNIB sent information on “Using a computer without vision” and “Notetaking” [13]. The former highlighted products that enable a blind person to use a computer, either by hearing in electronic speech what is displayed on the screen (mainly screen readers) or read on a Braille display (including Notetakers - portable devices for taking notes, etc, some with Braille keyboards) [13].

Whilst extremely useful information was gleaned, the solutions offered were not sufficiently inclusive. A prime example was the use of tactile diagrams and graphs aimed at blind and partially sighted people [9], for example “Tactile and large print maps of 3 London Underground (LU) Stations” using raised lines. These diagrams were in principle very pertinent, because the concept of the London Underground map was based on an electronics circuit and therefore relevant to the York exemplars. It was initially difficult to see how these diagrams could be made computer tractable. T3, prima facie, appeared to be a solution. The T3 [10] is a touch sensitive, multi-sensory device which provides instant audio feedback from tactile images. It enables visually impaired people to access graphical information. The T3 is connected to a standard PC or laptop computer via a USB connection and has a bespoke application to understand the diagrams on the tablet. To activate the system, a T3 tactile diagram overlay is placed on the surface of the device and touched by the operator’s finger. The T3 is the European version of the Talking Tactile Tablet (TTT) from Touch Graphics, New York. It requires tactile diagrams (such as the LU maps), so it would be necessary to create every combination and permutation of these for teaching electronics, too numerous to be practical or inclusive. The NCTD [9] states that Tactile Diagrams are useful when:

- The user is print-impaired and has some tactual ability.
- A novel concept not easily described in words, must be conveyed.
- A real object is unavailable for touching.
- The shape/form/pattern is important.
- Needed to illustrate scale and relationship: biology, maps, technology.
- Used as a reference: once, or as reminder.
- When it is necessary to enhance educational experience – variety.

Tactile Diagrams are not good:

- For fine detail.
- When extremely large.
- Without training.
- Without support materials.

These factors meant that they were not a suitable solution in the electronics domain. The most difficult hurdle was designing an interface that was both computer tractable and inclusive. The focus on inclusivity distinguishes this project from others such as: the TeDub system [11], a computer-based tool for visually impaired users, and; web-based haptic applications for blind people to create virtual graphs [14]. Coping with the number of combinations and permutations for the electronics exemplars also meant that any solution needed to be dynamic.

Guidelines have been suggested by Tiresias [12] on several aspects of computing for varying disabilities, but were highly specific, to web accessibility for instance. The most generic advice was the “User Needs Summary” dealing with each disability in turn. Specific to applications software were “Guidelines for Application Software Accessibility” [6]. These guidelines (2 priorities) covered application software running under any operating system or runtime environment. Priority 1 ensures that the application can be used by most people with impaired mobility, vision, hearing, cognition and language understanding, using their assistive technologies. Priority 2 makes it easier to use and will include more people with cognitive impairments or multiple disabilities. These guidelines were certainly inclusive.

The task analysis conducted with the student expert at Ulster proved to be most insightful. The student had had a period of being sighted and therefore was able to offer viewpoints with and without a visual and/or haptic memory of things. For example, the student had a visual memory of a grid, but only a haptic memory of resistors and capacitors. The student was therefore able to discriminate between what was meaningful to a visually impaired student who had a visual and/or haptic memory. This proved to be highly significant in terms of metaphors used. For example, when describing the pointer in a linked-list, a statement such as “might be thought of as a door to, in computing terms we express this as points to”, would be more appropriate for everyone and particularly those who have never experienced sight.

In relation to the senses utilized by the student expert for using computer interfaces, predictably, the main sense used was hearing; however sight was still above smell and taste. For everyday activities, hearing and touch can be interchangeable. The student, perhaps due to the possession of visual memory, still thought in terms of images. The student was able to touch-type (learnt whilst sighted) so used standard QUERTY keyboards for input and GUIs with screen readers such as Dream, for audio output. The student was unable to read Braille; this was considered a great disadvantage as there were major gains to be made from using Braille displays and printouts for checking computer programs for example. The recommendations from the student for interaction design were that: colour contrast can be of great immediate benefit for many partially sighted people; explanations using terms like “door, room, Lego” were meaningful to all; the best input and output devices were “anything tangible”, i.e. audio or tactile, with touch for orientation, keyboard for input; “hearing is serial, vision is parallel”. The student had used examples of raised maps for aircraft flight safety procedures, but since no reference point was given as to where the student was located on the aircraft or map, the map was meaningless. The student had no visual memory of AND/OR/NOT gates or their schematics. The student had some visual memory of programming, namely Visual Basic, prior to losing sight.

A circuit diagram is the result of a design process that begins with a specification and, for analogue circuits, amounts to calculating component values for resistors, capacitors, and so on as appropriate for the selected transistors. By example, students are taught how to analyse and design specific circuits in such a way that they should be able to abstract the analysis and design strategies and then apply them to other circuits. The circuit diagram is central during the teaching and learning process, rather than a supplement or final result. It is used directly during the exposition on how the circuit works, what limits its performance, and how to go about calculating the component values. Analogue circuits are thus an excellent focus for understanding how diagrams can be explained to the visually impaired.

Before students learn to analyse and then design, they need to be able to "see" the artefact on which the exposition is based; for the visually impaired this means that the connectivity must be painted in their mind's eye. A schematic-based circuit (lines interconnecting symbols and annotated with text) is sufficiently semantic to be automatically converted into a form suitable for a circuit simulator. This being so, a high-level oral description can also be generated; the question being: how should it be phrased? It is assumed that, in general, authors of course-ware that includes a spoken narrative would not be familiar with the needs of the visually impaired (including all that needs to be said). So, if possible, this extra information would be generated automatically by the computer.

The circuit diagram used is shown in Figure 1; it is more than suitable for illustrating the problems that the visually impaired would have if a computer spoke the description from its internal storage of that diagram. Three descriptions were created "by-hand", two (Figures 2 and 3) as if they had been automatically generated and a third version (Figure 4) created using a set of "human-empathic" rules and thought to be more difficult to generate automatically.

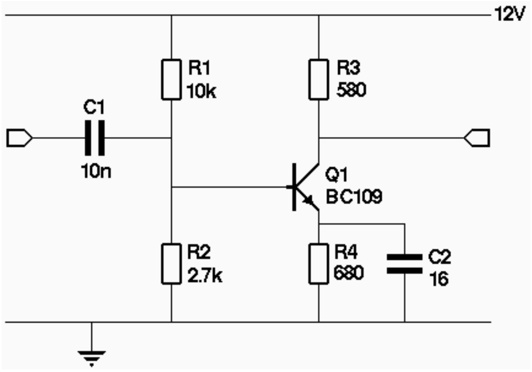

Figure 1: Circuit diagram

The three descriptions were presented at the task analysis: “Description by Components Top-to-Bottom, Left-to-Right”; “Description by location and node”, and; “Description – Human-orientated” (Figures 2 to 4, respectively). Due to the possession of visual memory, the second description was thought to be “more everyday language”, the third “more hierarchical”.

> *This is a common-emitter amplifier consisting of 1 input, 1 output, 2 capacitors, 4 resistors and 1 transistor. There is one power rail and earth. The input is connected to capacitor C1. Capacitor C1 is 10nF and is connected to an input, to resistor R1, to resistor R2 and to the base of transistor Q1. Resistor R1 is 10k ohms and is connected to the 12 volt power rail, to resistor R2 and to the base of transistor Q1. Resistor R2 is 2.7k ohms and is connected to resistor R1, to the base of transistor Q1 and to earth. Transistor Q1 is a BC109. The collector of transistor Q1 is connected to resistor R3 and to an output. The base of transistor Q1 is connected to capacitor C1, to resistor R1 and to resistor R2. The emitter of transistor Q1 is connected to resistor R4 and to capacitor C2. Resistor R3 is 580 ohms and is connected to the collector of transistor Q1, to an output, and to the 12 volt power rail. Resistor R4 is 680 ohms and is connected to earth, to the emitter of transistor Q1 and to capacitor C2. Capacitor C2 is 16uF and is connected to resistor R4, to the emitter of transistor Q1 and to earth. An output is connected to resistor R3 and to the collector of transistor Q1. That's a common-emitter amplifier.*

Figure 2: Description by Components

> *This is a common-emitter amplifier consisting of 1 input, 1 output, 2 capacitors, 4 resistors and 1 transistor. There is one power rail, 12 volts, and earth. On the left is an input connected to C1. On the right is an output connected to R3 and to the collector of Q1. R1 and, to the right, R3 are connected to the power rail at the top. R2, and to the right R4 and C2 are connected to earth at the bottom. R4 and C2 are connected in parallel. On the left is C1 connected to R1, to R2, and to the base of Q1. On the right, R3 is connected to the collector of Q1. R4 is connected to the emitter of Q1. C1 is 10nF, R1 is 10k ohms, R2 is 2.7k ohms, Q1 is a BC109, R3 is 580 ohms, R4 is 680 ohms and C2 is 16uF. That's a common-emitter amplifier.*

Figure 3: Description by location and node

> *This is a common-emitter amplifier consisting of 1 input, 1 output, 2 capacitors, 4 resistors and 1 transistor. There is one power rail and earth. The input is connected through C1, 10nF, to the base of transistor Q1, a BC109. The base of transistor Q1 is biased by the potential divider provided by R1, 10k ohms, and R2, 2.7k ohms. R1 is connected to the power rail (12 volts) and R2 is connected to earth. Q1's collector resistor is R3, 580 ohms, which is connected to the power rail. Q1's emitter resistor is R4, 680 ohms, which is connected to earth. C2, 16uF, is connected in parallel with R4. The output is taken from the collector of Q1. That's a common-emitter amplifier.*

Figure 4: Human-oriented description

The hierarchical structure was deemed to be an aid to cognition, however, the student chose the second description (figure 3) which was also the easier to implement. The student said that the following information was needed for navigating the web (or schematics, to some extent):

- “Where are you?
- What can you do?
- When do you know you’re there?
- How can you get back (not all pages have a home or back button)?
- Best naming convention for Lecture 15, slide 2 say, would be 15.2.
- Brief reminders of where you are at all times – just when moving on (not FROM WHERE, just TO WHERE), re. naming convention.
- Reference to Daisy navigation system for sectioning of books from RNIB.
- Textual description preferable to sound (audio icons).
- Speed of voice should be controllable, such as Talking books (RNIB), using something like Cont+Alt, though not directly available for those with physical impairments. Could be an issue with platforms. Could use arrow keys for navigation.
- Best to keep tone constant”.

The interview on electronics revealed that the student:

- Does not know about AND/OR gates or tables of data.
- Used a visual memory of a grid to understand the position of AND and OR gates, and truth tables. People without

visual memory would be unable to do this, as they would not be aware of grids.

- "Gate" was a meaningful term, but an OR gate poses a problem. You can visualise an everyday physical gate, but not an OR gate?
- Resistor/capacitor – tactile memory only.
- On having the first schematic diagram description read, the student was lost by the 4th stage (i.e. very early on).

The interview on a computer science on-line tutorial revealed that the student:

- Found pauses included in the present audio-aided visual presentation were necessary, else the presentation was too fast.
- Presentation could be improved by the use of male and female voices, male for the tutorial facts, female for the details (say).

For the follow-up meeting (task analysis) with the student it was decided to make use of the T3 device to create an example set of UML diagrams. As previously stated in the electronics example, it would be difficult and time-consuming to prepare all detail and levels associated with use-case and class diagrams. This is partly due to the requirement to "register" every diagram for the T3 device, to generate a unique key to each diagram. It is hoped that the prolonged use of the T3 device in some key examples in a second year module that uses UML, and also on the third year sandwich placement, would reveal more useful information on the best way to use this device. An alternative – more tactile solution was introduced and based on Lego. The factors to do with colour, size and board boundaries could allow for a more interactive non-computing solution. Could the student work around a diagram? Could they construct a diagram? If two or more boards were available could it represent stages of change or scale? It is hoped that the findings from this work over the next 6 months prove the use of a more tactile approach, particularly for non-Braille users.

4. CONCLUSIONS

The distributed cognition of the student expert was mainly acoustic. Understanding diagrams appears to be the crux of the problem. Learning something like UML for a computer science student would pose a major problem as it involves diagrams and programming code. If general diagrams are to be provided in some way as general text is provided, then the diagram must be in the form of a schematic representation rather than a bitmap picture and must be interpreted in much the same way as text should be interpreted with emphasis etcetera correctly placed.

For sighted people, diagrams reduce the cognitive burden and allow externalizing to reduce memory load [8]. Given that visually impaired people still only have a short term memory of seven plus or minus two items [1] with which to capture and appreciate an idea – the semantics, any cognitive burden needs to be reduced as much as possible. Any additional syntax will therefore get in the way.

The most poignant statement "hearing is serial, vision is parallel". Substitutions for visual information tend to be audio. Touch provides greater parallel input and output, but is not accessible to all, or as widely used or inclusive.

Criteria identified for interface design for visually impaired students:

- Solutions should be inclusive (suitable for sighted, partially sighted and blind users).
- Solutions should be computer tractable.

These criteria may be diametrically opposite.

- Solutions should be dynamic.
- Metaphors should be meaningful to all ("doors", "rooms", "Lego" not "points to").
- Touch is best for orientation.
- Sound is best for input and output, unlike Braille it is inclusive.
- Colour contrast can help a large range of (but not all) people – different platforms render different colours with different hues as different brightness.
- Inclusion can be aided by multi-modal and multi-media interfaces.
- High-level names which are well understood by all should be adopted, so that an individual's seven items are not overly compromised.
- An emphasis on naming items followed by their use should also help consolidate sighted people's learning.
- Superfluous information or detail needs to be suppressed.

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Lego is a registered trade mark.

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