Investigating the Accessibility of Program Selection Menus of a Digital TV Interface

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Abstract. We have investigated the accessibility issues of the program selection menus of a digital television interface. Initially we have simulated interaction patterns of visually and mobility impaired users and based on the simulation we have made changes to the font size and layout of the existing interface. Finally we have evaluated the new interface through a user trial involving people with disabilities. The results show that the new interface reduced the average time to select a channel and number of wrong channel selections for most of the participants.

1 Introduction

Many elderly persons and disabled people often get isolated from the society due to their disabilities and social issues. Television (TV) is a significant companion in their life to engage more fully with the world. Though there are legal, ethical and social reasons for designing products and services for people with different range of abilities, but still many people find the modern digital TV interfaces hard to use. We are working on the GUIDE project [20] that aims to develop a toolbox for providing adaptable, multi-modal TV interfaces and also helping designers to develop accessible interfaces for elderly and disabled users. In this paper, we have reported a study on accessibility issues of program selection menus of TV interfaces. We have identified the accessibility problems using a simulator and also used the simulator to propose new alternative design. Finally we have validated the simulation and new interface through a user study.

The paper is organized as follows. In the next section, we present background on the GUIDE project and our simulator. Section 3 presents related work followed by our study at Section 4. Finally we have drawn conclusions at Section 5.

2 Background

2.1 The GUIDE Project

The GUIDE project [20] is a medium scale focused research project on an EU FP7, Accessible and Assistive Information and Communication Technologies grant: “GUIDE – Gentle User Interfaces for Disabled and Elderly Citizens". It aims to develop a toolbox of adaptive, multi-modal user interfaces that target the accessibility

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requirements of elderly and impaired users in their home environment, making use of TV set-top boxes as processing and connectivity platform. For this purpose, the toolbox not only provides the technology of advanced multi-modal user interface components, but also the adaptation mechanisms necessary to let the UI components interoperate with legacy and novel applications, including the capability to self-adapt to user needs. The adaptation will be provided by modeling a wide range of capabilities of users. Figure 1 shows a schematic diagram of the GUIDE system. The GUIDE user model communicates with a middleware (the Adaptation Layer) of the GUIDE Hub which modifies application interfaces. The GUIDE user model uses a simulator to provide static (before interaction) and dynamic (during interaction) adaptation. The use of the user models and user profiles helps the system to address more varieties of users than existing similar system [9]. We shall use the following simulator for modeling users' interaction.

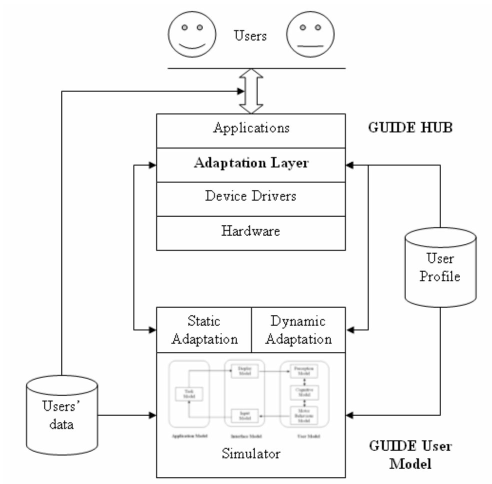

Fig. 1. Schematic overview of the GUIDE system

2.2 The Simulator

The simulator [4-7] embodies both the internal state of a computer application and also the perceptual, cognitive and motor processes of its user. It takes a task definition and locations of different objects in an interface as input. It then predicts possible eye movements and cursor paths on the screen and uses these to predict task completion times. The models are parameterized to represent different physical abilities, levels of skill and input devices. The simulator consists of a perception model, cognitive model and a motor behaviour model.

The perception model [5, 6] simulates the phenomena of visual perception such as focusing and shifting attention. It can also simulate the effects of different visual impairments (like Maccular Degeneration, Colour Blindness, Diabetic Retinopathy etc.) on interaction. We have investigated eye gaze patterns of able-bodied users as well as people with visual impairment and the model can predict the visual search time and eye gaze patterns of able-bodied people and a few types of visually impaired users (Myopia, Coour blindness and retinopathy [6]) with statistically significant accuracy. The cognitive model [4] simulates expert performance by using CPM-GOMS model [12]. It can also simulate performance of novices by using a dual space model [16]. The motor behaviour model [7] is developed by statistical analysis of cursor traces from motor impaired users. It quantifies the extent of impairment of a user by measuring his grip strength and uses it to predict movement time of a pointing task through a regression model. These models [4-7] do not need detailed knowledge of psychology or programming to operate. They have graphical user interfaces to provide input parameters and showing output of simulation.

3 Related Works and Our Approach

The GUIDE project plans to divide all possible sets of interaction with digital television into a finite set of scenarios and then investigating accessibility issues and providing adaptation for each scenario. This particular study considers a scenario of selecting channel and program from a menu. Previous work on menu selection investigated selection time of different menu items based on their position [15] and menu searching strategies [10] for able bodied users. Researchers worked on menu interaction for cell phones [13, 18] but there is not much reported work on accessibility issues of menus, in particular for digital TV interfaces. Existing approaches like target expansion [14] or target identification [11] are not very suitable for menu selection as menu items are more densely spaced than other types of targets like buttons or icons in a screen. Ruiz's approach [17] of expanding target region has also not been found to reduce menu selection time significantly. There is also not much reported work on the legibility issues of menu captions. Most researchers do not find difference in terms of reading time due to font types with respect to online reading tasks [1, 3, 8]. Though Bernard and colleagues [2] report significant difference in reading times between Tahoma and Corsiva fonts for a reading task of two pages, but the difference may turn insignificant during reading short captions. However, there is significant difference in reading time and legibility due to font size. Beymer and colleagues [3] prefer 12 point size while RNIB [19] and Bernard [1] prefer 14 point size.

Previous simulations [10, 18] on menu interaction mainly looked at cognitive aspects of interaction, but did not consider people with disabilities. We take help from our simulator [4-7] in identifying the accessibility problems of program selection menu with respect to visually and mobility impaired users. Based on the results of the simulation we have designed new interfaces. Our study consists of the following three stages

1. Problem identification through simulation
2. New interface evaluation through simulation
3. Validation of the simulation through a controlled experiment

4 The Study

Initially we have designed the following interface (Figure 2) which looks similar to existing systems (Figure 3). The GUIDE project [20] explores accessibility issues of people with a wide rage of abilities (including visual, cognitive and motor impairment) using different modalities of interaction (like pointing, keypad, gesture, voice based inputs and so on). In this particular work, we have investigated problems faced by people with visual and mobility impairment. Loss of visual acuity is one of the main symptoms of many visual impairments like Myopia, Maccular Degeneration, Diabetic Retinopathy and so on. Another significant type of visual impairment that affects vision without reducing visual acuity is colour blindness. Regarding mobility impairment, several types of motor impairment like stroke, cerebral palsy, dystonia or polio result significant spasm or tremor in finger which impedes users to use a remote control. However some of them can use a mouse, touch pad or trackball to move a pointer across the screen. So we have analyzed

- Sensory problems of
  - People with less visual acuity
  - People having colour blindness
- Interaction problems of
  - People with motor impairment using a pointing device

In this particular study, the simulator takes a sample task of selecting a menu item and the screenshot of the interface as input and shows the perception of visually impaired users and cursor trajectory of motor impaired users as output. In the simulation study, we have not bothered about the particular words used as captions since the simulation results are not to be used by participants. We use captions like Channel 1, Program 1 or Time 1 as captions. However in the validation study we used different words as captions and discussed it in detail in section 4.6.

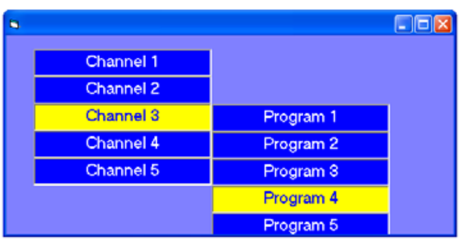

Fig.2. Control Interface

Fig. 3. Actual interface

4.1 Problem Identification

Initially the output from the simulator is used to identify accessibility problems. Based on the simulation results we identified the following two accessibility issues

- Legibility of captions
- Spacing between menu items

Figure 4 shows the redesigned interface. We have increased the font size of captions for users with visual impairment. For people with motor impairment, we have changed the size of the buttons without changing the screen size such as no couple of buttons shares a common boundary. It should reduce chances of missed clicks. We have also investigated the effect of severe visual acuity loss for the following six font types, however the legibility is not much different for different font types and nearly same for all.

Sans Serif	**Serif**
Microsoft Sans Serif	Sabon
Veradana	Times New Roman
Arial	Georgia

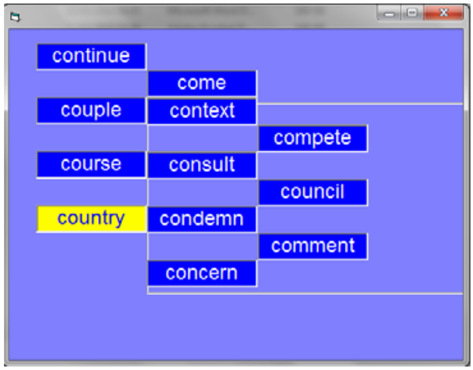

Fig. 4. New Interface

We evaluated the new interface with the following controlled experiment. In this experiment we hypothetize that

- People with visual acuity loss and motor impairment will perform a task faster and with less number of errors in the new interface (Figure 4) than the unchanged version (Figure 2).
- People with colour blindness will perform a task equally well with respect to people with no impairment (control group) in the unchanged version of the interface (Figure 2).

We measured the task completion time as a measure of performance and the number of missed clicks as a measure of errors.

4.2 Procedure

The procedure mimics the process of selecting a channel from a list followed by selecting a program from a drop down menu. Initially, the participants were shown a channel name and a program name. Then they made two selections matching the previously shown channel and program names. We did not use real channel and program names to avoid any biasness of users. The first two letters and length of all the captions were kept nearly same to avoid any pop-out effect [21] of the captions during visual search. We used the Veradana font type due to its bigger *x*-height and character spacing than other conventional fonts. Each participant repeated the task ten times. All participants were trained before undertaking the study.

4.3 Material

We used a standard optical Mouse and an Acer Aspire 1640 Laptop with a 15.5” monitor having 1280×800 pixel resolution. We also used the same seating arrangement (same table height and distance from table) for all participants.

4.4 Participants

We collected data from two institutes, National institute of Orthopedically Handicapped at Kolkata, India and Papworth Trust at Cambridge, UK. All participants have some experience of using computers- either they were learning or using computers regularly. All of them volunteered for the study.

4.5 Results

The average reaction time (total time needed to select the channel and program) was less in the new design than the control design (Figure 5) though the difference was not statistically significant in an independent sample two-tailed *t*-test ($t\ (120,1) = 0.64$, $p > 0.05$). The average number of missed clicks were also less (Figure 6) in the new design than the control design though the difference tends to statistical significance in a Wilcoxon ranked test ($W\ (120,1) = 163$, $p = 0.1$). In the experimental condition (new deign) missed clicks occurred in 21 trials while it occurred 31 times in control condition.

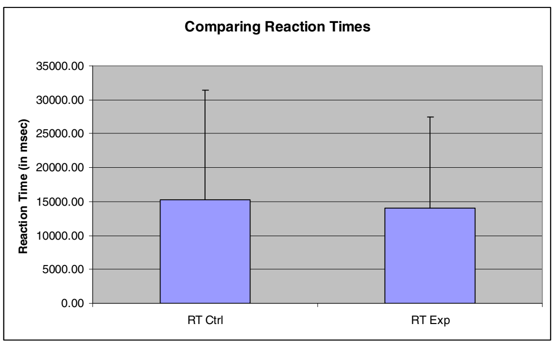

Fig. 5. Comparing reaction times

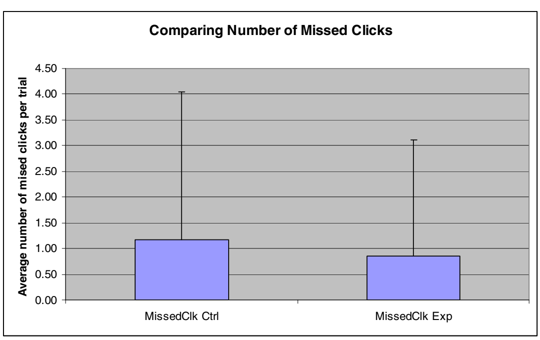

Fig. 6. Comparing number of missed clicks

We have also analyzed the reaction times and missed clicks for each individual participant. Table 2 shows the average reaction time and total number of missed clicks for each participant. It can be seen that 4 out of 12 participants (P4, P5, P8 and P9) have an average reaction time greater for the experimental condition and only 2 out of 12 participants (P8 and P12) missed clicked more in the experimental condition than the control condition.

4.6 Discussion

The reaction time and number of missed clicks were both less in the new design though we failed to find any statistical significance of the difference. Most of our participants do not have any problem in moving hands and thus they can control the mouse movement pretty well. Except participants P1, the visual acuity loss was also

Table 1. Participants

Participants	Age	Sex	Impairment
P1	>45	M	No mobility impairment. Age related Hypermetropia (+3.75 / +3.25 Dioptre)
P2	25-45	M	Difficulty in walking, right leg is shorter than left leg. Mild Myopia (- 2.75 / -2 Dioptre)
P3	25-45	M	Right hand was cut in accident, no impairment in left hand. No visual impairment.
P4	25-45	M	No mobility impairment. Lost vision in right eye, left eye is perfect.
P5	25-45	M	Left arm is affected by polio, no impairment in right hand. No visual impairment.
P6	<25	F	Lower body is affected by polio from birth, no impairment in hands, wheelchair user. No visual impairment.
P7	<25	M	Difficulty in walking from birth. Slight Myopia (-0.7 / -0.7 Dioptre)
P8	44	M	Cerebral Palsy reduced manual dexterity also some tremor in hand wheel chair user. Slight loss of visual acuity.
P9	63	M	Left side (non dominant) paralysed after a stroke in 1973 also has tremor
P10	31	M	Cerebral Palsy reduced manual dexterity wheel chair user.
P11	>45	M	Reduced manual dexterity in limbs due to neurological problem, wheel chair user.
P12	44	F	Did not mention disease restricted hand movement no tremor. Slight loss of visual acuity.

Table 2. Result per participant

	AvgRT Ctrl (in msec)	AvgRT Exp (in msec)	TotalMC Ctrl	TotalMC Exp
P1	3886	3259	0	0
P2	5755	5033	0	0
P3	7230	6149	0	0
P4	21777	26838	72	56
P5	4481	4611	0	0
P6	12195	11739	11	4
P7	15628	6747	13	0
P8	15394	18628	20	28
P9	7213	9184	0	0
P10	36160	25084	11	0
P11	20752	20550	14	8
P12	32228	30223	0	6
Avg	**15225**	**14004**	**11.8**	**8.5**

not severe. Additionally in the present experimental set up, a missed click did not waste time while in a real interface a missed click will take the user to an undesired channel and getting back to the previous screen will incur additional time. So the higher number of missed clicks in the control condition will also increase the channel selection time further in an actual scenario. However in future we plan to run the study with more cautious selection of participants. All of the visually impaired participants preferred the bigger font size. However a few participants reported difficulty in reading the zigzag presentations of captions of the new interface. In future we also plan to use an eye tracker to compare the visual search time for both types (linear and zigzag) of organizations of menu captions.

In this study, we have investigated the accessibility of program selection menus for a digital TV interface. Future studies will include more interaction modalities (like keypad or gesture based interaction), devices (like remote control, set top box and so on) and impairments (like cognitive impairments). However the results of this study can be extended beyond program menu interfaces of digital televisions. For example, the font size of captions in absolute terms (x-height ≈ 0.5 cm.) indicates the minimum font size required for any text in an interface for serving people with severe visual acuity loss. Similarly the particular colour combination of the screen (white text in blue background) can be used in any other interface as well to cater people with colour blindness. Finally the modified menu structure can be used in computers or other digital devices to make the menus accessible to people with mobility impairment.

Unfortunately we did not get any participant with colour blindness. So we have used a colour blindness filter (from Cambridge Research Systems, http://www.crsltd.com) to simulate the effect of dichromatic colour blindness. In this case, we did not find any significant difference in reaction times in an independent sample two-tailed t-test (t (20,1) = 0.81, $p > 0.05$)and did not record any missed clicks as well.

5 Conclusions

In this paper we have investigated the accessibility issues of digital television interfaces. We simulated interactions of visually and mobility impaired users. Based on the simulation, we recommended change of the layout and font size of menu captions and designed a new interface. Finally, we evaluated the new interface through a user trial involving users with visual and mobility impairment. Though we failed to find any statistically significant difference between the existing and new design but the new interface reduced the average time to select a channel and number of wrong channel selections for most of the participants.

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