Design and User Evaluation of a Joystick-Operated Full-Screen Magnifier

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ABSTRACT

The paper reports on two development cycles of a joystick-operated full-screen magnifier for visually impaired users. In the first cycle of evaluation, seven visually impaired computer users evaluated the system in comprehension-based sessions using text documents. After considering feedback from these evaluators, a second version of the system was produced and evaluated by a further six visually impaired users. The second evaluation was conducted using information-seeking tasks using Web pages. In both evaluations, the 'thinking aloud protocol' was used. This study makes several contributions to the field. First, it is perhaps the first published study investigating the use of a joystick as an absolute and relative pointing device to control a screen magnifier. Second, the present study revealed that for most of the visually impaired users who participated in the study the joystick had good spatial, cognitive and ergonomic attributes, even for those who had never before used a joystick.

Categories & Subject Descriptors:

H.5.2 [Information Interfaces and Presentation]: User Interfaces — evaluation/methodology

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Design, Human Factors, Experimentation

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Joystick, screen magnifier, visually impaired users

INTRODUCTION

A screen magnifier is a software program that is loaded into the computer's memory and remains active so as to magnify the text and graphics that appear in programs and applications run thereafter [1]. Screen magnifiers are used mainly by visually impaired people with sufficient functional vision (sometimes referred to as people with residual vision). There are a significant number of

commercial screen magnifiers, for examples see [3]. They provide a number of features, one of the most prominent of which is the proportion of the magnified computer display, which can be any one of: the complete screen, 'full-screen magnification'; a significant portion of the screen (often around half the screen), 'area magnification'; or the area under the mouse pointer, 'magnifying glass' [2, 4]. This paper focuses exclusively on full-screen magnification because informal observation indicates that this mode is by far the most widely used mode of the three.

Despite the fact that screen magnifiers are widely used, there are few known studies investigating the usability of screen magnifiers with their intended users (e.g., [5]). Many studies seem to rely on the opinions of software developers or researchers as sufficient for a "usability" test (e.g. [3, 8]). This lack of evaluation with visually impaired users can retard the acceptance and adoption of the products by their intended users, especially because screen magnifiers nowadays are becoming increasingly feature laden, possibly in an attempt by developers to gain competitive advantage. Although these additional features may prove beneficial to more experienced users, they may hamper novice users and those who have problems mastering the interaction with computer systems. It seems appropriate, therefore, to investigate the usability of magnifiers with visually impaired users in order to determine which features these users considered essential. The work reported here goes some small way towards realizing this goal by evaluating some of the more common and essential features.

The function of a screen magnifier is to present an enlarged view of the user's area of interest. The magnifier determines the area of interest to be the current 'focus' [2, 4], which is presented by the screen magnifier in a manner dependent on the current context of operations. The current context is determined from: the mouse pointer position; the cursor position (in for example a word processing application); and changes in operating system or application state resulting in, for example, a pop up window. For the most part users do not explicitly interact with the screen magnifiers; they simply interact with the computer in the normal way, using a mouse and a keyboard and the current focus changes according to their activities. Generally the user is required to exert little explicit control

of the operation of the magnifier. It is only when he/she needs to change some aspect of the magnifier's settings (for example, the magnification level) that he/she issues direct commands, typically through the keyboard.

We propose that joystick, rather than standard mouse and keyboard control of screen magnifiers, may be of benefit for some users, especially non-expert computer users. There are a number of reasons for this:

- A joystick can be used as an absolute pointing device (i.e. the position of the joystick corresponds to the position of the mouse pointer and hence to the portion of the screen that is enlarged– for further discussion see below). Our intuition is that joystick control should be easier for users to understand because, unlike a mouse, it has a well-defined spatial reference point (the center position). Work elsewhere has compared and evaluated mouse and joysticks for authoring hypermedia-based user interfaces. The results are not clear, with some blind authors reporting that the mouse offers advantages (e.g. [13]) while in an academic discussion forum some researchers have argued that, theoretically at least, a joystick is easier for a blind person to use (e.g. [7]). Another study also reported the successful use of a joystick for a multi-modal game operated by non-sighted users [10].

- A joystick may be easier to control (i.e. grasp and move) than a mouse for some users, especially people with minor dexterity or haptic problems that are brought on or exacerbated by age or other physical limitations. A previous study found that the use of force feedback devices (such as a force feedback joystick) was particularly beneficial for users with motion impairment who faced problems with keyboards and mouse [9].

- Modern joysticks (especially those that are designed for the control of computer games) typically have many buttons and other controls. These can be mapped to functions that control the configuration of the magnifier (e.g., setting magnification level), so that the user can control the settings with only the joystick rather than having to switch back and forth between the joystick and the keyboard or the menu items on the screen (as is usually the case when the screen magnifier is controlled with a mouse): such switching may be problematic for users with visual impairment. This approach may also make the functions easier to remember by novice users because they will be able to uniquely associate each function with a particular button or control.

GOALS OF THE STUDY
The study described in this paper had three goals. The primary goal was to determine how easy or difficult visually-impaired people found joystick control of a screen magnifier. The second goal was to evaluate some features associated with joystick control of a magnifier (for example to evaluate different modes of operation – details are given later). Finally, the study also aimed to evaluate some of the

common features provided by commercial magnifiers with their visually-impaired prospective users.

SCREEN MAGNIFIERS AND THE USE OF JOYSTICKS
Common Features of Screen Magnifiers
In this section we describe some of the common screen magnifier features.

The degree of magnification is variable. Users can enlarge an image in integer multiples between 2 and 16 times [6], although some magnifiers provide enlargement of up to 32 times. Some magnifiers also allow independent control of magnification in the horizontal and vertical axes. Although when horizontal and vertical magnification levels differ, the enlarged image is distorted, it is thought that some users benefit from this feature. In typical use the vertical magnification is set to be greater than the horizontal magnification for text processing activities in an attempt to optimize the trade-off between the readability of characters (i.e. by making the characters larger) against the readability of words and sentences (by maximizing the amount of text that is visible on the screen).

The user has control over the screen colors. In the simplest systems (including the one used in this trial) the user is limited to the original presentation or an inversion of the colors. Typically, black text on a white background is color-inverted to give white text on a black background, which gives better contrast for some users. In other magnifiers the user can select the background and foreground colors from a more extensive set of color-schemes; yellow text on a blue background and amber text on a black background are widely used.

Most commercial magnifiers provide an option for smoothing the enlarged image [6]. This feature is present because when the image is enlarged it can, for the reasons described in [4], appear 'blocky'. It is thought that 'blocky' text is difficult to read and thus magnifiers employ algorithms that 'smooth' the text. Fig. 1 shows enlarged text both with and without smoothing.
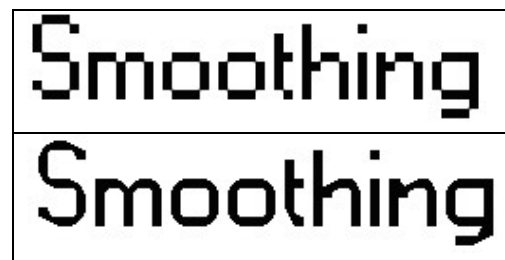

Fig. 1. Text without (upper) and with (lower) smoothing

Finally, some systems provide a "panning window", an uncommon feature in magnifiers [8]. A panning window when activated indicates the current focus by means of a highlighted block on the full non-enlarged screen image. This feature is intended to allow the user quickly to obtain an idea of where the current magnified portion of the screen fits into the whole screen. In addition, the user can move the highlighted block around the full screen and select the area of the screen that he/she wishes to become the current

focus. This allows the user to select directly areas of the screen that present information (such as tool bars and menus) in particular areas of a window.

Magnifier Used in this Study

The magnifier used in this study, 'Magnus 1.0' [1][4], is a commercially available screen magnifier. Magnus is intended to be competitive with commercial screen magnifiers, but has a deliberately restricted feature set of basic features that are considered (but not yet evaluated as being) essential.

Magnus provides screen enlargement from 2 to 16 times magnification with independent control of horizontal and vertical enlargement. It provides simple color inversion (e.g., black becomes white etc.) rather than providing full user selection over colors. Smoothing can be turned off and on by the user and a panning window is provided.

Joystick Control

The joystick is used for two purposes in Magnus. Firstly, to control the position of the mouse pointer (in general use) or the cursor (in applications such as word processors and spreadsheets)[2]. Secondly, the joystick buttons can be used to control the configuration settings of the magnifier.

Control of Cursor Position

Generally, the joystick controls the cursor position in an 'absolute positioning mode'. This means that the tilted angle of the joystick corresponds directly to the area of the full image that is shown as the enlarged image on the screen. In this mode, to view the top left corner of the image, the joystick is tilted away from the user and to the left. The user holds the joystick in this position until he/she wishes to view a different part of the screen. In effect, each position of the joystick presents a different enlarged portion of the full, unmagnified display to the user. To explain this by analogy, one could imagine the full computer image, prior to enlargement, being written on a piece of paper. Above the piece of paper is a magnifying glass, which is capable of viewing only a small portion of the paper and transmitting it to a computer monitor. In absolute positioning mode, the position of the magnifying glass relative to the paper is controlled by a direct mechanical linkage between the joystick and the magnifying glass. In some respects this is similar to a pantograph[3].

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[1] A screen magnifier called Magnus was developed in the mid 1990s and it is this program that is referred to in [3]. The 'Magnus' described in this paper is a completely separate development (see [4] for architectural considerations).

[2] In the following text, we use the term 'cursor position' to refer to both application cursor and mouse pointer position.

[3] A pantograph is "a jointed framework of rods based on the geometry of a parallelogram, for copying drawing, plans, etc. on the same, or a different scale"[15]

Magnus also allows a user to control the cursor position using a 'relative mode'. In this mode the displacement of the joystick from its center position causes the magnifier to move the current focus in the same direction. The image will continue to move in that direction until the joystick is again centered, the edge of the screen is met, or the joystick is moved to indicate a new direction of travel. To modify the analogy given above, it is as if the direct mechanical linkage between the position of the magnifying glass and joystick position were broken and the magnifying glass' position is controlled by motors that drive two rack and pinion gears with the magnifying glass mounted on a pair of orthogonal rods that connect to the gears. In this mode, there is no direct correspondence between the position of the joystick and the image on the screen. The motivation for including this mode was to provide a fine control mechanism to complement the coarser control of the absolute mode.

THE USER EVALUATION

Participants

In the first evaluation seven registered blind users with some residual vision participated in the study. There were two females and five male participants with a mean age of 50.9 years (S.D. = 17.80 years) and a mean of 9.2 years of prior computer experience. Six of the users had used a screen magnifier before, but none had used Magnus; four of the users had prior experience of using a joystick with computer applications.

In the second evaluation, six other registered blind users with some residual vision participated in the study. There were four females and two males with a mean age of 39.0 years (S.D. = 20.83 years) and a mean of 8.3 years of prior computer experience. Three of the users had used a screen magnifier before, but none had used Magnus; two users had prior experience of using a joystick with applications.

The reason for recruiting a different group of participants for the second cycle of evaluation was to prevent familiarity affecting participants' comments and feedback. However, there is a drawback in doing so. Comparative evaluation between the first and second designs of the application cannot be performed.

Procedures

The evaluation sessions, for all but one participant who performed the evaluation in the authors' laboratory, were conducted at a computer-training center for blind and visually impaired people in the North West of England. Only one experimenter (the same experimenter performed all sessions) and the participant were present in the evaluation sessions, except for one session with a deaf participant where a translator was also present.

At the beginning of the session the participants were informed that the purpose of the session was solely to test the usability of the joystick-operated magnifier. The participants were then asked to fill in a short questionnaire to acquire demographic data and to record their past

computer experience. The questionnaire, which was printed in Arial 24pt, also served to determine that the participants had some residual vision.

The participants were given a brief tutorial on the magnifier and the joystick interface and were then allowed to practice for 10 minutes with support given by the experimenter. In the first evaluation, participants were given four comprehension-based tasks to carry out. In the second evaluation, information-seeking tasks were given. No time limit was set for the tasks during which the participants were encouraged to think aloud and comment (favorably and negatively) about features of the magnifier and could, if they desired, ask questions of the experimenter. The experimenter also asked questions of the participants to clarify their comments and the experimenter's observations.

At the end of the session the participants were interviewed to ascertain whether there were any issues that had not been mentioned in the session. The questions were either function-specific or general. The function-specific questions were open-ended questions asking the users' opinions on all of the tested functions (e.g. "Please give your opinions about the font smoothing function"). The general questions asked were as follows:

1. Did you find the joystick easy to use? Did it perform according to your expectations?

2. Did you find the magnifier program easy to use? Did it perform according to your expectations?

3. Do you think it will be easy for you to master this magnifier?

4. Are there any features that you would like to see added?

5. Are there any features that you would like to see removed?

Each session, from introductory questionnaire to post-trial interview lasted around an hour. The experimenter's observations and the participants' comments were recorded in a real-time written report.

Equipments and Stimuli
The tests were carried out using a laptop computer with a 1GHz Pentium processor, 512 MB memory, running Windows 2000 Professional. The screen was a 15" active matrix LCD display with resolution set to 1280 x 1024 pixels with 32-bit color resolution.

The first cycle of evaluation
A Microsoft ForceFeedback 2 joystick was used because it is one of the most popular joysticks on the market [12] and because it offers a wide range of buttons that can be used to control magnification options. The force feedback element of the joystick was not enabled. This meant the joystick offered little resistance to movement and, once displaced from its central position it did not spring back into place. Magnus 1.0 was used as the screen magnifier.

The mapping between features and buttons is shown in Fig. 2. The mapping was decided by the development team.

The 'fire' button, not shown in Fig. 2 because it is on the opposite side of the stick, was mapped onto the left mouse button. Magnification was controlled by the throttle; the user moved the throttle away from him/herself to increase magnification and in the reverse direction to decrease magnification. The three buttons marked 'on/off' acted as toggle switches, (the first depression turned the feature on, the second off, etc.). The panning window was active only while the associated button was held down. The absolute vs. relative movement button was used to toggle between the two positioning modes.

Fig. 2. The mapping of control buttons to magnifier features in the first tested joystick.

The participants used the screen magnifier to seek answers to comprehension-type questions from two sets of documents (taken from http://www.aarp.org) presented in Microsoft Word XP. Each set of documents contained four articles arranged into two columns with two articles in each column. The questions were chosen carefully to ensure that without reading the articles the users would not be able to answer the questions. Each article was roughly 150 words long and presented in 10pt Arial font, black text on a white background as is commonly found in online newspapers. The questions were read to the participants and the experimenter recorded the answers. Because the purpose of the study was to perform a user evaluation of the joystick-controlled screen magnifier, the participants' answers were not recorded and they were allowed to move to the next question if they could not find an answer for a particular question. Participants were also allowed to end their participation at any time.

The second cycle of user evaluation
A Saitek Cyborg 3D joystick was chosen by the authors for this second cycle of evaluation. This choice was based on various users' comments and feedback (see Results and Analysis). The mapping between features and buttons is shown in Fig 3. Similar to the first cycle of user evaluation, the mapping was decided by the development team. Most of the functions implemented in the first tested joystick operated in a similar way with this joystick (e.g. the magnification was controlled by the throttle). The trigger was used as a toggle switch for the auto scrolling function rather than being mapped to the left mouse button.

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The participants used the screen magnifier to find some information (an image, a word and some data in a table) and click some links in locally stored Web pages (adapted from http://www.bbc.co.uk) presented in a Mozilla Web browser. Again, the purpose of the study was to perform a user evaluation; the participants' answers therefore were not recorded and they were allowed to give up if they could not find the requested information or end their participation at any time.
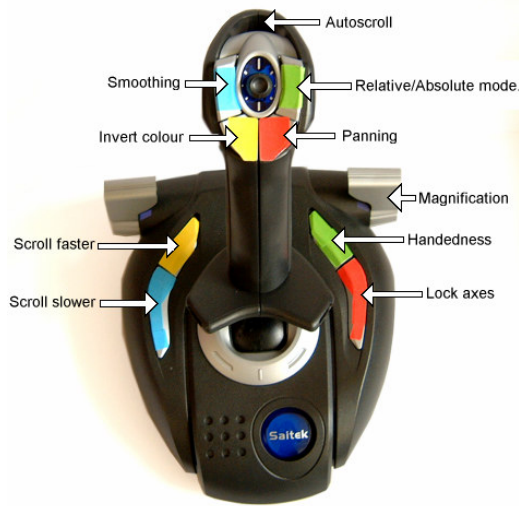

Fig. 3. The mapping of control buttons to magnifier features in the second tested joystick.

RESULTS AND ANALYSIS

The features that participants liked and disliked were identified from the experimenter's observations, the participants' comments recorded during the experiment and the participants' answers to the usability-related questions.

Overall, most participants indicated that they felt that with some practice controlling the screen magnifier with the joystick would be easy to master, although some indicated that at the time of the evaluation they found it rather difficult. Indeed, some researchers have suggested that a more meaningful usability evaluation can only be done through a longitudinal study (i.e. to observe the ease of learning as well as the ease of use) rather than a snapshot study [14]. They also stated that the screen magnifier matched their expectations (excluding some usability-related problems described below). However, one participant in the first cycle of user evaluation and two in the second cycle indicated that they preferred to use a keyboard to control the magnifier instead of the joystick. In the second cycle, a participant indicated that he would normally use the text enlargement features of his web browser rather than a screen magnifier.

Favorably Received Features

Feature #1: Color Inversion.
As noted earlier, Magnus allows the users to invert the presentation of the color (i.e. from black to white and vice versa). Ten users preferred to view the screen in negative

contrast (white text on a black background). One preferred black text on a white background – a very common website color scheme – one was equally happy with both styles of presentation, and one said that he always viewed the screen in its original presentation with no intention of changing it. One user who liked the negative contrast also stated that providing negative contrast was essential for users with Age-related Macula Degeneration (AMD), and hence really appreciated the feature's inclusion.

Feature #2: Auto Scrolling.
This feature was not intended but was a fortuitous consequence of implementing the relative positioning mode. It manifested itself in the following way. Because the joystick was not utilizing its force feedback abilities (these were deactivated in the joysticks used in the cycles of evaluation), when a participant tilted a joystick and released it, the joystick remained tilted. Because of the nature of the relative positioning mode, leaving the joystick tilted caused the screen to continue to scroll in the direction indicated by the joystick. If this is used to provide a constant scroll to the right, it provides a convenient feature when the participant needs to read a line of text. If the word processor's cursor remains at the beginning of the line, then when the scrolling focus reaches the end of the line and the user presses the down-arrow key, the cursor moves to the beginning of the next line down and the screen magnifier begins scrolling again from the left hand side of this next line. Thus, with a tilted joystick and use of the down-arrow, the text can be scrolled through line by line with little human intervention. In addition, in relative mode the distance from the joystick's central position is proportional to cursor speed: the users could therefore control the speed of scrolling to match their own reading speed. However, the participants found that very accurate positioning of the joystick was needed to match these two speeds (see usability-related problems below).

Based on the users' feedback, in the second cycle of development this auto-scrolling function could be selected by pressing and releasing the joystick's trigger, which most participants found easy to use. The speed controls were assigned to two buttons (one for faster speed and another for slower speed), and pressing and releasing the button caused the speed to change by one 'speed increment'. Most of the participants indicated that they would prefer a continuous speed control (i.e. the speed changes gradually but constantly while the button is held down) rather than the discrete control provided (which required repeated depressions to effect the desired change). In addition, one participant thought that the slowest scrolling speed possible was still too fast for their reading speed.

Overall, the participants responded favorably to the automatic scrolling feature and most recognized that providing variable speed control would ensure that a wide range of users with different reading speed would be accommodated.

Feature #3: Positioning Modes.

As noted earlier, the relative mode was provided to give users fine control compared with the relatively coarse level of control provided by the absolute mode. However, the participants viewed the two positioning modes as different scrolling speeds (relative = slow, absolute = fast) rather than types of positioning as originally intended. They did, however, report favorably on the two modes and stated that each mode had its own strong points. One user stated that the absolute positioning mode would be particularly useful for novice users because this mode was spatially easy to understand, while the relative positioning mode was more useful for expert users who can have better fine control over the joystick. Another user suggested that the absolute positioning mode was useful for 'browsing' the screen (i.e. getting an overall view of the screen) while the relative mode was good for 'searching' for a particular item.

Feature #4: Smoothing.

Most participants reported favorably on smoothing, especially those that used high levels of magnification, although some did not notice the difference, possibly because of the extent of their visual impairment. One user disliked smoothing. One user who liked smoothing stated that smoothing was important for users with AMD.

It should be noted, however, that smoothing requires more computer processing, which results in a longer delay between a user's movement of the joystick and the corresponding movement of the screen focus. One user noticed the resulting degradation in responsiveness but did not consider it a problem.

Feature #5: Control of Magnification Using the Joystick's Throttle Control.

Participants used the throttle to choose the magnification level that best suited their needs (which vary depending on the font size of the document or Web page). Moving the throttle away from oneself increased the magnification while moving it toward oneself decreased the magnification. All participants reported favorably on this feature because they easily understood the mapping between the throttle and the magnification level. This feature was the most favored joystick control for most users.

Usability-Related Problems

Problem #1: Over-Sensitivity and Lack of Precision of the Joystick.

There were a number of problems reported with the joystick used in the first evaluation. It was perceived as being over-sensitive and insufficiently precise, which lead to a number of issues. Firstly, it proved difficult for the participants to stop the movement of the screen focus when they desired. This proved frustrating for the participants, especially as some were not familiar with the desktop and all were reading the documents for the first time. All the users lost their orientation. Secondly, the participants found it difficult to maintain their desired speed and line. One elderly participant was concerned for other users of his

age group, who may have trembling hands that may amplify this problem. In deed, a previous study comparing the use of a mouse versus a joystick found that the physical construction of the joystick made it susceptible to tremor in a manner that the mouse was not [11]. The joystick also had a significant degree of inertia, which often caused participants to overshoot their desired location (in absolute positioning mode) or move too fast (in relative positioning mode).

Further research is needed to investigate whether the problems that the participants faced in the first cycle of evaluation were unavoidable because of the nature of the joystick (for example [11] reports that joysticks are harder to control than mice) or whether the particular joystick chosen was inappropriate and that better joysticks exist. If the problem is universal in joysticks, there may be software solutions that can be incorporated into the design of the magnifier. The participants recommend two solutions to this joystick problem: to use a joystick with more resistance; or to provide the user with the means to limit movement to one direction only. Both suggestions were implemented in the second cycle of development, which was conducted with a different joystick.

From the experimenter's observation, users had fewer problems controlling the joystick used in the second cycle of evaluation, perhaps because this joystick has more resistance than the joystick used in the first cycle.

There were mixed comments on the directional lock. Some participants said that it was a good feature but could not think of the applications where it would be particularly useful. Some stated that it was not useful because they were confident they could control the joystick without the help of the directional lock. One user said that the lock would help users orienting. In general, most participants could use the feature with few problems.

From various comments in the second cycle of evaluation, we could speculate that the problems faced by the participants of the first cycle of evaluation were not a result of joysticks in general being difficult to control but a result of the particular joystick used.

Problem #2: The Location of the Buttons.

The participants commented unfavorably on the positioning of some of the buttons of the joystick used in the first cycle of evaluation. These buttons were those toward the back of the joystick's base (see Fig 2). There were several problems. Firstly, the participants found it difficult to distinguish one button from one another because all four buttons were of the same shape and color. Secondly, when in use, the stick obstructed the view of the buttons. In some cases, participants tried to locate the buttons by touch and in doing so accidentally altered the position of the throttle (causing the magnification level to change) or moved the joystick (causing the screen focus to move). Some participants overcame these problems in time, but others experienced them throughout the experiment. Some participants suggested that using better visual cues, such as

shape or color, or altering the position of the buttons might lead to significant improvements.

Following the participants' suggestions, a new joystick (see Fig. 3) was used in the second cycle of development. This second joystick had buttons with different shapes and the throttle was located further away on the far side of the joystick buttons, thus reducing the possibility of accidental movement of the throttle. The buttons of the new joystick were also larger and for the user evaluation cycle were marked with different colors to help the participants recognize the buttons and recall the associated functions more easily. Most participants commented favorably on the coloring of the buttons except for one participant who was color-blind.

Problem #3: Panning Window.
As noted earlier, a 'panning window' in Magnus allows a user to determine where the enlarged image is relative to the overall unmagnified screen image and to move quickly to another part of the screen. In the first cycle of user evaluation, participants commented unfavorably on this feature and gave several reasons for their negative reactions. Firstly, the joystick's lack of precision meant that it was difficult for the participants accurately to select the area that they wished to view. When the magnified image of the selected area was presented, they discovered it was not the view that they wanted. This caused a loss of orientation and necessitated further (unsuccessful) use of the panning window Secondly, in order to view the panning window one of the joystick's buttons had to be held down whilst the joystick was moved. The button was then released when the selection block had moved to the desired location. Most users found this synchronization difficult to achieve and suggested that instead the panning window should be toggled on and off.   This was implemented for the second evaluation so that, rather than holding a button down when moving the joystick, users depressed and released a button to enter panning mode and depressed and released the same button again to select the desired area. Finally, and perhaps most significantly, because the participants are visually impaired they could not see the unmagnified screen in detail and could only get an impression of the position of the magnifier window in the original screen image; hence they did not find the panning window useful.

In the second cycle of evaluation the first two problems appeared to have been resolved and the participants found the feature more useful. However, the third problem remains. This feature needs further evaluation with tasks that require the user to select specific parts of an application's window; to, for example, select items from a tool bar or menu. It may be that because these items have a fixed position in a window, users may be able to locate the correct screen focus by using their knowledge of the layout of the application's window rather than having to examine the detail presented on the unmagnified screen image. However, this supposition will prove true only if the user

can recognize the boundaries of the application window on the screen or when the application window is maximized.

One user (who called this feature a 'zoom-in feature') suggested that the panning window might be useful for graphical packages or maps, while others, despite commenting that it was a good feature, did not use it to complete the given tasks.

There was one additional problem with the panning window. When the color inversion was activated and the magnified image was in negative contrast, activating the panning window changed the contrast back to positive contrast, which one user found to be unpleasant and suggested that the panning window mode maintained the user-chosen contrast.

Problem #4: Task-Specific Features.
In the first cycle of evaluation the participants' task was to read text presented in two columns.   Because the participants discovered the scrolling feature (described earlier), they expected to be able to scroll down a column (rather than across both columns to the edge of the document). One user overcame this problem by noting that if the down-arrow key was pressed when the scrolling reached the right-hand side of the left-hand column, the scrolling window would return to the start of the next line of text in the left-hand column. Another user abandoned the joystick altogether, and preferred to read the text by navigating using the up- and down-arrow keys.

In the second cycle of evaluation, the task was of information-seeking nature on a set of web pages and this feature was of less use. It therefore needs to be validated in a purely text-reading test.

Problem #5: Implementation –Related Problems
In the first evaluation two problems associated with the implementation of the magnifier were identified. Firstly, when a user moved the throttle to change the magnification level, the screen focus changed to the magnifier's control panel. This was intended to show the user the current configuration of the magnifier, including the magnification settings. However, it caused the enlarged region to be centred on the control panel and caused users to lose their orientation. Moreover, the users could not see what effect the changes in magnification were having on the area that they were trying to read; the numerical presentation of the magnification level was not helpful in this regard. Secondly, the maximum magnification level was related to the speed at which the user moved the throttle: the faster the movement, the lower the maximum magnification level. This meant that sometimes the level of magnification desired by the user wished could not be obtained, so the user would assume it was unavailable.

These problems were addressed prior to the second evaluation and the participants of this cycle commented favourably on the use of the throttle to control the magnification level.

CONCLUSIONS AND FURTHER WORK

Despite the problems discussed above, the results of the experiment indicate that it is feasible for real-life users to control a screen magnifier with a joystick. Further studies are needed to determine whether a joystick is better than a mouse, the keyboard or other control mechanisms (for example touch pads); a comparative study is planned. Other possible further studies might concentrate on the use of this screen magnifier when using a wider range of applications (e.g. e-mail clients, spreadsheets or graphics packages). Finally, the present study is limited to users reviewing and searching for information or application content. The results may not be generalizable, especially to applications that require users to be aware of the layout of the application interface itself (for example applications with buttons and toolbars or when the user is creating or editing documents themselves).

One significant issue the users raised in the evaluations is the set of positioning modes. From the experiment it seems that absolute and relative modes are both used, but it was not clear which situations favored one mode over the other, although there was some indications that the relative positioning mode was easier to control than the absolute positioning mode due to the lower speeds of movement available with the relative positioning mode.

Of the general features of magnifiers, smoothing and color inversion were most appreciated by the users. Of the joystick control, the use of the throttle to control the magnification level was the most favored and intuitive feature for the users.

The 'panning window' was disliked in the first evaluation, possibly because it was difficult to control. In the second evaluation users commented more favorably on the function. As noted earlier, this feature may need to be evaluated with tasks that require access to fixed menus and tool bars.

Finally, the participants found the automatic scrolling to be useful (and would have perhaps found it more useful had it been aware of column breaks). We can speculate that this is potentially a useful feature of screen magnifiers.

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