Research Review

Iconic Representation in Human-Computer Interfaces

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Abstract

This article reviews studies done on iconic representation of commands in human-computer interfaces. The studies reviewed provide data and make recommendations on topics such as the benefits of icons, icon placement, configuration and size, as well as accessibility of icons for users who are visually impaired, either due to limitations in the surroundings in which the interface is used or in the users' physical ability. The data reviewed here encompasses work from the past 20 years. Human-computer interface design has evolved immensely in this time period, therefore a general limitation of the earlier studies on the benefits of utilizing icons in these interfaces results from a more established set of standards as well as the sheer prevalence of icons. Ultimately, icons are best used in conjunction with text labels and alternative ways to command the application; and icons should be designed as large as possible considering the limitations of screen size/resolution and workspace requirements of the interface. Additionally, auditory and tactile ways of representing icons are more recently being evaluated by researchers. The specific guidelines that this review presents is somewhat inconclusive besides a general understanding that providing users with alternative ways of "seeing" icons when vision of the interface is impaired is more effective than not.

Introduction

Graphical icons on computer interfaces were developed to help make these interfaces much more accessible and easy to use. As computer interfaces become more prevalent, technology advances, and design evolves, it becomes more important to understand how best to present and incorporate icons within the design of a computer interface. Human-Computer interface design seeks to discover the most efficient way to design understandable electronic messages. It is a field that is continuously evolving as technology advances, giving professionals and researchers in this area of study more possibilities of design. Icons originally helped computer users to use direct manipulation in order to accomplish a task on a computer. Direct manipulation involves allowing the user to physically interact with files and directories, and presenting a visual representation of the progress. For instance, dragging the iconic representation of a picture file to the Recycle Bin on a Windows Desktop is an example of direct manipulation using icons. Although this theory and practice aided in the usability of computer interfaces, it is still limited to users who do not experience visual impairment, whether it be due to environment, or physical ability. Direct manipulation using icons has become so commonplace in computer interfaces, in order to make the use of these interfaces more accessible, research has been conducted on creating audible and tactile icons for those who are experiencing visual

impairment. The studies reviewed in this document include basic research on where icons should be placed on a computer interface, how many and which configuration is optimal, and what the ideal size of icons should be. Additionally, it will discuss studies on how best to make icons more accessible using newer tactile and audible icon technology.

Review

Reasons to Use (or not use) Icons

Some studies on the benefits of icons revealed that when compared to text, there were no significant advantages in using iconic representations over text-based representations of actions and objects (Benbasat & Todd, 1993). Furthermore, icons were found to be slower than text or text plus labels because users took fewer steps using icons, but more time per step (Egido & Patterson, 1988). On the other hand, some studies have shown that icons improve the usability of a computer interface. It has been found that icons are visually more distinctive than words (Maguire, 1985) and they can be easily recognized (Gittins, 1986), icons' syntax are simpler than commands, such as in a command line prompt where a user would be required to either remember or look up the text associated with a specific command, which may be why icons require less learning time than text commands (Lodding, 1983). Additionally, icons are international symbols which rarely need to be modified based on language or cultural differences (Lodding, 1983).

Icon Placement and Arrangement in UI Design

Some research suggests that frequently used menus or icons should be permanently visible on a computer interface (Grobelny, Karwowski & Drury, 2005). This being the case, there will be many icon arrays that will be located in dialogue boxes or pop-up menus that are not permanently located on the screen. For icons in this mode, studies have shown that these windows, especially with a larger number of icons, should be built in compact configurations - ideally square or possibly horizontal (Grobelny, Karwowski & Drury, 2005). Further research by Grobelny and Karwowski the following year provided more conclusive data against vertical arrangements of icons, however, if this type of configuration is necessary, it should be located near the right side of the screen (Michalski, Grobelny, Karwowski, 2006).

Optimization of Icon Size and Number of Icons

In a study by Steckler and Smith, it suggests that users' threshold range for the size of small icons is 7mm-8.6mm (Steckler and Smith, 1996). Subsequent studies have shown that an icon size of 5mm is acceptable for users using small screens such as mobile devices (Chu, Goldstein, Anneroth, 1999). Fitts' Law, a mathematical model that represents the relationship between speed and accuracy of a human's rapid, aimed movement, has been used to describe users' performance on selecting a desired icon in computer interfaces (Grobelny, Karwowski & Drury, 2005). This application of Fitts' Law allows for researchers to imply that large icons are recognized and obtained

quicker than small icons. However, there are limitations on the size of icons on a computer screen or within a computer application, for instance, too large of icons limits the number of icons that can be available. Also, if icons are taking up too much of an application's interface, either due to a large number of icons or a large icon size, this limits the workspace available. For instance, if MS Word used the largest icons possible in their toolbars, there would be very little visible screen available to word process. Therefore the size of icons tends to be ideal between 12mm-16mm, using smaller icons when the number of icons is increased to more than 8 and using the larger sized icons when the number of icons is 8 or less (Grobelny, Karwowski & Drury, 2005). Additionally, this study also suggests that the number icons in pop-up menus should be minimized as much as possible since it takes users longer to find icons when their location is less familiar, such as in this instance where a user's action initiates a dialogue box to appear. Subsequent research by Grobelny and Karwowski suggests a new mathematical model, which augments the more simplified Fitts' Law, to describe how users recognize and select a targeted icon taking into consideration the cognitive processing time necessary to identify that icon (Michalski, Grobelny, Karwowski, 2006):

$$\mathbf{MT = 3361 - 4.56 \times \mathit{Size} + 0.00399 \times \mathit{Size}^2 - 19.6 \times \mathit{Hor} + 26 \times \mathit{Dis}.}$$

Where MT = mean acquisition time in milliseconds

Size = the size of graphical elements included in examined panels (since all studied structures contained square objects, a side width in TWIPs was taken as item size)

Hor = horizontally defined as a ratio of panel width to its height

Dis = panel dispersion specified as a quotient of the longer side of the graphical structure to the shorter edge

Expanding Accessibility by using Auditory and Tactile Icons

Whether or not icons have made computer interfaces more usable, they are so commonly used in software applications and operating systems throughout the world that icons have become a familiar standard in interface design. As a result of the prevalence of icons, issues arise when the visual display of the interface is difficult to see or is not available. Such cases may be for those who are visually and/or hearing impaired, either by their environment, such as excessively bright, dark or loud surroundings, or limitations in physical ability. There have been many technological advances in the last 20 years to help make interfaces more accessible. A large part of that initiative involves communicating the meaning of icons to those who cannot visually see them. Consequently, there have been studies to help provide some data on which techniques work best. There are auditory icons, earcons, spatial auditory icons, and tactons that have been developed to help compensate for a lack of visual access to computer interfaces. Auditory icons, sometimes referred to as representational earcons, provide the user with a metaphoric sound that

symbolizes what the icon is intended to represent, scissors cutting for clicking on the "cut" icon for instance. Earcons are more abstract and the mappings more arbitrary, associating pitches or groups of pitches with specific icons to differentiate the icons from one another. Once the pitch and compound pitch mappings to visual icons have been "learned" by the user, these sounds have been shown to be more effective for representing icons audibly than short bursts of sound (Brewster, Wright & Edwards 1994). Spatial auditory icons are similar in sound to auditory icons; however, they utilize changes in pitch and localization in order to give the user an indication of how close and in which direction nearby icons are located. When a user's mouse cursor is to the right and below the "cut" icon and to the left and below the "copy" icon, the spatial auditory feedback would project the cutting sound from the right and behind the user and simultaneously project the copying sound from the left and behind the user. Tactons utilize frequency, amplitude, waveform, body location, duration and rhythm, mapped to specific icons providing users with a tactile representation of the icon. When designing for visually impaired users, spatial auditory feedback of icons should be used over ordinary icons or non-spatial auditory feedback whenever possible (Barreto, Jacko & Hugh, 2007). It has also been found that the use of tactons is beneficial to the user in areas such as wearable computing where screens are limited or in interfaces for blind people where there is no visual display (Brewster & Brown, 2004).

Discussion

Application for Design

As described in the review above, research has implied conflicting suggestions on the benefits of using icons in interface design. Regardless of the studies indicating that icons are no more beneficial then text representations of actions, icons are prevalent in computer interfaces today. Ultimately, the standard has shifted over the past 20 years and many icon designs have become universal. For instance, regular computer users recognize the scissors icon as representing the cut command and the disk icon as representing the save command. The studies that have been conducted suggesting that icons do not add value to human-computer interfaces, do however reveal that icons with a text label are most effective. Tooltip technology allows the user to hover over an icon to see the text label, without having to take up excessive space on the interface with permanent text labels for icons. This has helped to alleviate the divergence on the benefits of icons from the results of the studies mentioned in the above review. Furthermore, the same commands available through selecting icons are also available through drop down menus and keyboard shortcuts in most applications. In conclusion, icons are best used in conjunction with other possible ways to select actions.

When icons represent actions in human-computer interfaces, their optimal size, number, configuration and location within the application have been researched extensively. For the most part, designers should strive to make icons as

large as possible given the limitations of screen size and resolution. The trade-off in icon size is the application workspace and the number of icons necessary, therefore on a Windows desktop, since workspace is not necessary, icons' size is simply limited by the number of icons permanently available on the screen. On the other hand, in an application, such as Adobe Photoshop, the main workspace should be given the most possible space, which consequently limits the area available to permanent icons. In these cases, icons may need to be smaller to accommodate the workspace size and dialogue boxes of icon arrays may be used. It is recommended that the configurations of the icons within these dialogue boxes should be square if possible or horizontal, avoiding vertical formations, while any frequently used icons should be permanently available within the interface. Initial research on interface design with icons modeled a user's acquisition of a desired icon to Fitts' Law, however, subsequent research analyzed additional configurations of both permanently affixed icons as well as pop-up menus to find a more specific equation for acquisition time of an icon. It was found that Fitts' Law doesn't always apply since there is usually a level of cognitive processing that is involved in completing a task such as identifying an icon and selecting it. This cognitive factor becomes more apparent when icons are not permanently affixed to the application interface, such as in pop-up menus of icon arrays which are more commonly used in response to the limitations discussed above. This new model provides some insight for interface designers to determine how best to incorporate icons into the design of application interfaces. This information can help to determine which icons should be located permanently on the interface and which should be added as pop-up menus.

Limitations of Research

Most applications offer the user a level of customization of icons to users. This customization could include adding text only, text + icon or icon only; which icon dialogue boxes should be available permanently, and even where on the interface these dialogue boxes should be located. As the flexibility that users are given in configuring the interfaces of their applications increases, the decisions about icons designers need to make becomes less significant. This advancement in UI design may decreases the relevance for further in depth studies on icon arrangements, size, and location.

As technology advances in the field of icon accessibility, more conclusive data is needed to determine how best to present iconic representations of commands in audible and/or tactile ways.

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