Seminar Report: Fisheye Techniques

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ABSTRACT
Multi-faceted and complex domain applications have often been associated with the visualisation of large-scale information. As the system structures continue to expand, fisheye strategy is said to provide a constructive approach to overcome the space problem in information layout through the utilization of focus-and-context mechanism. However, there are also studies, in which this presentation method is claimed to be less desirable in the renderings of complex data. Therefore, this paper reviews and discusses the usability of the fisheye techniques in information visualisation from a cognitive perspective. It begins with an introduction of the fisheye concept and an overview of its related subsets. Then, a range of existing fisheye techniques and their corresponding trade-offs are examined, followed by an analysis of their practicalities in various domains. Finally, the usability of fisheye menus is revisited, including a set of suggestions for implementation improvements.

Author Keywords
Fisheye Views; Information Visualization; Focus and Context.

INTRODUCTION
Fisheye strategy in computer displays was first proposed by Furnas (1986) in his paper called *Generalized Fisheye Views* to help cope with the existing information overload problem. Adopting the concept of *focus and context,* the ultimate goal of these views is to offer presentation of local details while maintaining its semantic significance in a global context. By using small data visualization within a large-scale information structure, users can pay greater attention to the details in their current focus point and acknowledge only the increasingly important features that are further away. In order to generate these views, Furnas has suggested a fisheye formalism that involves determining the user's *Degree of Interest* (DOI) towards certain object in the examined information space. This DOI will then take into account both factors of *A Priori Importance* (API) and *Distance* (D). API represents the importance of the featured object, whereas D denotes the object's proximity to the user's current focus of interest. The DOI function at any given point x, is defined as

$$DOI_{FE}\ (x|fp) = F\ (API(x), D\ (fp, x)),$$

Equation 1. DOI function (Furnas, 1986)

where "fp" is the current focal point, and F is a subjective geometry function that allows generalization of this formalism to various domains. This formulation implies that each data item's size in the fisheye views is proportional to its corresponding degree of interest, as shown in Figure 1. In other words, the size of the within-focus objects is relatively bigger than the out-of-focus ones (Furnas, 1986).

Over the years, a range of fisheye strategies have been proposed and implemented by numerous researchers to view large information spaces. All of them vary in the context of their data structures, visualization approaches and their dependency on the semantics of the application (Schaffer et al., 1996; Turetken, Schuff, Sharda & Terence, 2004). According to Furnas (2006), such scenario is an example of the deployment of the generalized fisheye DOI function in different domain structures, which then leads to the subsequent generations of various *fisheye DOI subsets* (FE-DOI subsets). The FE-DOI subsets consist of *Distortion Views, Zoomable User Interfaces (ZUI), View+Overview or View+Closeup, Multi Resolution Display* and lay a fundamental platform for deriving different types of fisheye visualization. Despite the diverse methodologies, these variants of fisheye techniques have been developed based on the similar underlying concept of focus and context (Furnas, 2006).

Figure 1. Fisheye View (Turetken et al., 2004)

The description about the FE-DOI subsets and their related trade-offs will be elaborated in the next section. Besides exploring what and how the fisheye views can provide, three other core issues will be examined in this paper. The first will study a number of extensions to the preceding fisheye techniques. Then, this paper will concentrate on analyzing the usability of fisheye techniques in supporting user tasks in various domains - both their assets and drawbacks. The discussion of this area will be supported by analysis of different related evaluation papers, which are conducted to investigate the usability of the fisheye, specifically in graph displays and navigational menus. While Bederson (2000) suggests the promising use of fisheye techniques in the task of selecting menu items, and Darling, Recktenwald, Kalghatgi and Burgman (2005) promote the use of fisheye views in displaying large graphs; Hornbæk and Hertzum (2007) reinvestigate the usability of such techniques in data item selection, primarily as opposed to the hierarchical menus. The third issue to be addressed in this paper is how the users perceive the fisheye views, along with the suggestions to improve the fisheye interface implementation.

DESIGNS AND TRADEOFFS

The use of fisheye strategies relies considerably on the application's structures and the effectiveness of resultant conceptual visualization in matching the end-users needs (Schaffer et al., 1996). Therefore, the following subsections compare and contrast a range of FE-DOI subsets in terms of their implementation designs

Distorted Views

In this design, data objects with higher degree of interest will be distorted and appear larger within the global context. There are many techniques to create the distorted view in the information space. Some interface designers have directly followed up the formalism of FE-DOI, to decide how much visual space to be allocated to the DOI area in a distorted manner, whereas others have used geometric approaches and differential magnifications.

Adopting the formalism of FE-DOI explicitly, Sarkar and Brown (1992) implement graphical fisheye views for graphs by using two-dimensional planar and polar geometric transformations with filtering and multiple focal points. Other implementations such as Mackinlay, Robertson and Card's *Perspective Wall* (1991), Robertson, Mackinlay and Card's *Cone Tree* (1991), Robertson and Mackinlay's *Document Lens* (1993) and Lamping and Rao's *Hyperbolic Browser* (1994) have adopted certain geometric algorithms to create distorted views with the aim of achieving a balance of focus and context. The Perspective Wall and Cone Tree utilize a three-dimensional visualization and provide the basic fisheye property by offering a smooth transition between detail and context (Sarkar & Brown, 1992; Bartram, Hot, Dill & Henigman, 1995) whereas the Document Lens uses reduced magnification to display pages surrounding the current focal page (Pook, Lecolinet, Vaysseix & Barillot, 2000). In addition to that, stretching functions have also been used in Sarkar, Snibbe, Tversky and Reiss's *Rubber Sheet* (1993) to assign distorted views relative to their focus. It provides multiple foci and allows user to determine the screen space for areas of interest (Schaffer et al., 1996).

Distortion techniques manipulate aspect ratios of geometric representation in regions and shape alterations in order to achieve the effect of focus and context. However, due to the changing of shapes and regional aspect ratio, this design can lead to the user's uncertainty and misapprehension towards the whole topological layout and its intended contents. The users may not be able to understand that there are distortions in shape and position of the information space. As a result, the users will be confused with the perceived information visualization (Furnas, 2006; Zanella, Carpendale & Rounding, 2002).

According to Bartram et al. (1995), Sarkar and Brown's graphical fisheye (1992) renders impressive images but the resulting view may be deemed "too distorted and unnatural" (p. 208). As for Sarkar et al.'s Rubber Sheet (1993), the interaction is regarded as burdensome because the users execute on the rubber sheet containing the object rather zooming in directly. Also, Furnas (2006) commented on the use of distorting reduction technique in the Document Lens to be less useful in portraying the context of the information. It is because the reduction of surrounding pages may have been excessive and results in a loss of structural semantics of the visualization.

Many studies have stated that view distortions can negatively affect user's judgments of distance, alignment, and angle on the layout. As a response to that, Gutwin and Fedak (2004) have compared user performance on layout tasks with three types of fisheye lens that generate distorted views - full-screen pyramid lens, constrained hemispherical lens and constrained flat-topped hemisphere lens (as shown in Figure 2). They find that task accuracy is higher with constrained lenses compared to full screen lens. This study shows that despite there are drawbacks in displaying layout through distortion, it is still feasible particularly with the use of constrained lenses.

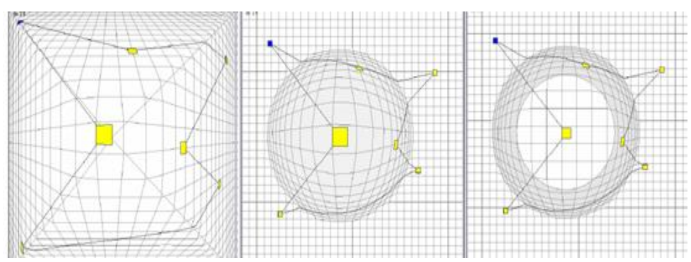

Figure 2. Left to right: full-screen pyramid lens, constrained hemispherical lens and constrained flat-topped hemisphere lens (Gutwin & Fedak, 2004).

Zoomable User Interfaces (ZUI)

This design has adopted a "non-distorting magnification techniques" in portraying the focus and context view. It is said to be the multiplicative form of the FE-DOI function because the union of concentric zoom matches the subset of Eqn. 1 precisely (Furnas, 2006, p. 1000). In a study by Bederson and Hollan (1994), they introduced Pad++ as a "natural substrate" for representing abstraction of layout by using semantic zooming (p. 18). With this approach, the object details can be obtained when zoomed in for a close focus. When it is zoomed out, a different representation of context is displayed to maintain its semantic structure. In semantic zooming, the appearance of an item changes non-geometrically with size so as to stay meaningful (Furnas, 2006).

Despite the ZUI design does not utilize the distortion technique that may have caused misapprehension; it still requires a considerable amount of user mental operations. In this approach, zooming into a part of information space shows local details, but loses the overall structure of the visualization. On the other hand, zooming out of a local region for orientation will cause insufficient regional details (Sarkar & Brown, 1992; Schaffer et al., 1996). This design expects the users to keep track of the previous views when they zoom in or out the context.In this case, the users tend to get lost in the information space during their navigation and may in turn lead to a decrease in its ease of learning (Furnas, 2006; Zanella et al., 2002). For example, it is not clear in Pad++ how a portal affects another in the global environment when the users zoom into an infinite of two-dimensional sheet of paper (Bartram et al., 1995).

View+Overview or View+Closeup

These two displays are closely related to magnification-based focus and context techniques. View+Overview approach displays a selected detailed area in large, with a smaller window at the corner displaying the overview of the context. In contrast, View+Closeup approach shows the global context in large, with a smaller window presenting a close up of a selected region. This design does not involve geometric distortion but uses multiple views simultaneously, showing different scales of the layout (Furnas, 2006; Zanella et al., 2002).

This design may result in topological discontinuity at the edges between views. The users have to switch between information spaces and this may increase task completion time (Furnas, 2006; Zanella et al., 2002). Not only the multiple views require extra screen and force the users to mentally integrate different scenes, this approach also exclude the parts of the graph that are adjacent to the enlarged view, resulted in loss of context (Sarkar & Brown, 1992; Schaffer et al., 1996).

Multi Resolution Display

This design technique does not apply any distortion or zooming effect, but simply adjusts the display resolutions - higher in focus area, lower around it. This method is said to be a FE-DOI filter, manipulating the spatial frequency domain explicitly. However, this approach is deemed less efficient in displaying different regions of interest within the overall information context due to its lack of viewing cues and ability to display different regions in obvious contrast (Furnas, 2006; Zanella et al., 2002).

EXTENSIONS

Due to the limitations in each FE-DOI subset, the researchers try to balance the tradeoffs by merging some of the discussed design techniques in their fisheye view implementation fittingly to their respective domains. This section explores different studies that employ variations of FE-DOI subsets to achieve the enhanced fisheye view for the optimal visualization of information.

Schaffer et al. (1993) proposed a *Variable-Zoom* algorithm for generating fisheye views of hierarchical clustered networks. Similar to Sarkar and Brown's graphical fisheye view (1992), their approach allows users to manipulate selected nodes in a limited way and offers multiple foci in a single window; but what differs them is that Schaffer et al.'s visualizes hierarchical clusters in progressive detail, as well as the nodes of the graph. This variable-zoom method combines distorted views and ZUI techniques to provide the focus and context of structured networks. This study concluded that the variable-zoom views had considerably improved users' task performance due to the faster navigation and less redundant exploration. In the later enhancement, Schaffer et al. (1996) improved the algorithm by supporting overlapping nodes.

Variable-zoom method exhibits a good use of hybrid approach to provide potentials of distorted views and ZUI designs. However, apart from opening and closing the network clusters, the users do not have control over the sizes of the nodes, making the interaction rather inflexible and the transition between views is abrupt. Therefore, Bartram et al.(1995) developed a related approach called *Continuous Zoom* to present focus and context with multiple focus points to deliver the visualization in an adaptable manner. This method allocates information space more efficiently by using a dynamically calculated DOI for simultaneous multiple zooms, combined with the automatic system sizing. When a cluster is closed, it gives up screen space for the sibling clusters to grow. Not only the users can switch between views with better continuity and smoother transition, they can control the amount of space allocated to each space region by opening and closing clusters, as well as resizing nodes. Bartram et al. also stated this approach could minimize disorientation by maintaining the relative node locations, making it superior than the traditional ZUI and distorted view designs.

Shi, Irani and Li (2005) also implemented fisheye distortion and zooming techniques for browsing elements in TreeMap, a common space-filling representation. Inspired by Schaffer et al.'s Variable Zoom approach (1993, 1996), they provide a technique that allows the users to open data elements and view the contents without opening successive layers of hierarchy. In addition to that, Shi et al. had conducted two experiments to evaluate the effectiveness of the approach. Both experiments suggested that the users perform faster in browsing and locating objects with the distortion and zooming techniques, compared with the traditional drill-down approach.

Besides that, Reinhard, Meier and Glinz (2007) presented a *Fisheye Zoom* algorithm to visualize and edit graphical hierarchical models. This algorithm is an extension of Bartram et al.'s Continuous Zoom approach (1995), with the improvements in the layout restructuring process. In the Continuous Zoom approach, only one global scaling function is used. As a result, it scales the whole layout even when the size of just one node is modified. Moreover, this approach does not allow model editing when a node is zoomed in because the zoomed geometry is only a scaled projection of the underlying basic geometry. In order to overcome these limitations, the Fisheye Zoom algorithm, on the other hand, uses different scaling functions and does not scale the whole layout globally when there is a change in node sizes. Instead, it produces a new layout and dynamically adjusts the new sizes and positions of the node and its siblings. It excludes the use of fixed basic layout and thus allows users to edit during the element is zoomed.

ASSETS

Many studies have been made to investigate the usage of fisheye techniques in the information display since the *Bifocal Display* approach by Spence and Apperley (1982) and most of them have advocated this approach as a predominant element in the visualization of information structures. This section illustrates the advantages of fisheye views and explores the benefits that this strategy can offer in different areas.

It is important to provide a focus and context mechanisms in the display because it assists the users extract the semantic meaning of certain information from its relative surroundings (Furnas, 2006). An individual data item brings no significance unless it is perceived together with its relative context as a whole. According to Furnas (1986), Spence and Apperley (1982) and Zanella et al. (2002), the visual capabilities of fisheye techniques is said to reduce human effort in information processing across separate views because it amplifies human ability for visual gestalt.

Besides offering an interface for better information visualization, fisheye techniques are said to provide an effective traversal, by using various traversal schemes like Fisheye Lens and ZUI movements, with which the users can follow a direct link to reach successively remote items (Furnas, 2006). In addition, Schaffer et al. (1993, 1996) has mentioned that the fisheye techniques are of advantage in path finding task. Also, Bederson (2000) and Baudisch et al. (2002) studied that the users will react faster in steering task when the focus region in provided in a global context.

The potential use of fisheye strategies expands to various domains. Turetken et al. (2004) promoted the beneficial use of fisheye view in supporting system analysis and design processes. They incorporated fisheye techniques into their data flow diagrams and allowed the system designers to view the sub process in details while maintaining its context. According to their study, the focus and context effect provided by fisheye views helps system designers identify interrelated components and eliminate redundancy easily. Quicker navigation in such views has also significantly increased the efficiency of system design. Thus, Velázquez-Iturbide (2006) applied logical fisheye views in a programming environment to optimise the visualization of functional expressions.

The usability of fisheye techniques has been further promoted by several researchers. Darling et al. (2005) evaluated the promising use of fisheye techniques by conducting a study to compare user performance in visualising connections between nodes using two distinct view types – fisheye and tree. An experimental prototype called *FocusTree* was implemented to display such views and the users were asked to count the number of links that exist between two nodes. Results showed that fisheye views were superior to tree views in term of task completion time, accuracy and user preference. Therefore, Darling et al. concluded that fisheye strategies could increase user's ability to identify "degree of separation" between two nodes in a complex graph (p. 1330).

DRAWBACKS

Despite many researches are supporting this approach, fisheye views are still not widely accepted. In this section, the shortcomings of this technique will be discussed and the usability of fisheye menus will be re-examined based on a contributive experiment results from Hornbæk and Hertzum (2007), which oppose the preceding usability study performed by Bederson (2000).

It is said that the fisheye interface distorts the presentation of data and can cause steering problem and object targeting. For example, Gurwin's work (2002) has discovered that the error rates and target acquisition times of the users is actually higher while using fisheye views due to the effects of magnification. Besides that, some interface designers tend to avoid the use of fisheye interface in the layout presentation due to their concern about the extent of "misinterpretation and confusion", to which the distortion of the fisheye techniques may have resulted in (Zanella et al., 2002, p. 119). In addition, the user may feel discomfort and get distracted easily during the use of fisheye interface due to the lack of previous interaction experience with such views.

Earlier, Bederson (2000) has conducted a study to evaluate the usability of the new mechanism called *Fisheye Menus*, as shown in Figure 3. This approach has been proposed to support users in selecting data items from a long-list menu. In his assessment, fisheye menus are being compared with three other existing menu approaches -- hierarchical cascading menus; scrolling arrows; and scrollbars. While the latter two techniques show relatively lower level of preference, he preliminarily concludes that the fisheye menus are preferred by the users in task browsing and these menus may be faster than traditional hierarchical ones.

However, this result may not be deemed absolutely precise by Hornbæk and Hertzum (2007), and therefore, a further study called *Untangling the Usability of Fisheye Menus*, has been performed as a response to Bederson's work (2000). Hornbæk and Hertzum have commented that the previous usability result of fisheye menus may have been interfered by the index of letter as viewing cues. Also, in their experiment, they have concluded that the conventional hierarchical menus are "the most accurate and by far the fastest", compared with fisheye menus (2007, p. 6). The hierarchical structure, as shown in Figure 4, allows users to apply shorter fixation and scan path in locating data items, advocating lower mental activity requirements and visual search from the users. Nevertheless, both of these studies have agreed that - while fisheye menus are more superior in tasks browsing, hierarchical menus are preferred for goal-directed tasks.

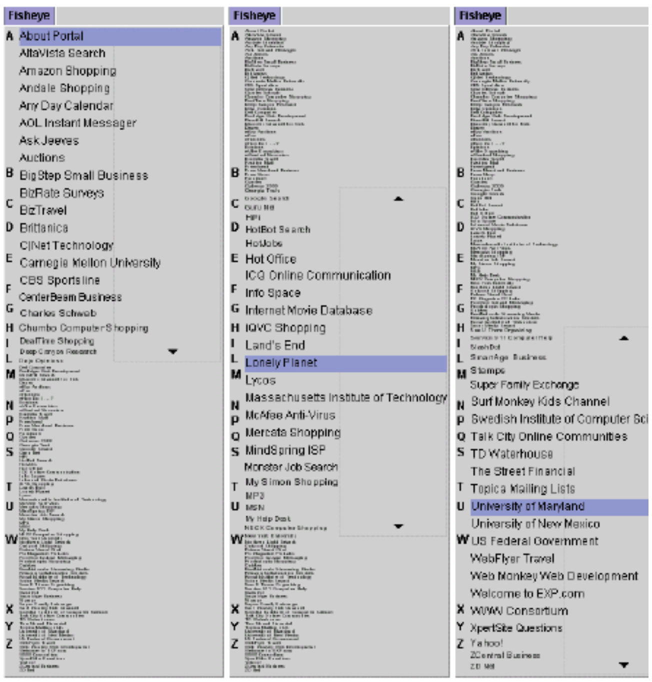

Figure 3. Fisheye menus at different cursor positions (Bederson, 2000).

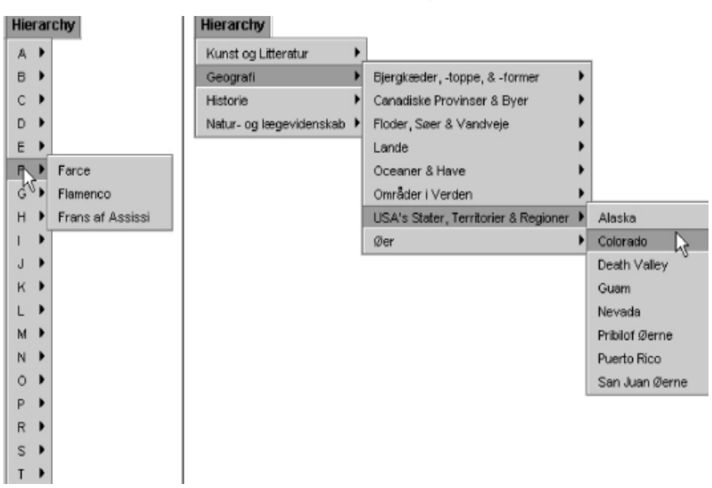

Figure 4. Hierachical menus at different cursor positions (Hornbæk and Hertzum, 2007).

IMPROVEMENTS

In order to increase the usability of fisheye interface that employs distortion views, helping the users comprehend the existence of distortions in the layout is fundamental. It is suggested that using grids as viewing cue in fisheye views can notably enhance a user's ability to locate data items with higher level of accuracy and speed (Furnas, 2006; Schafer & Bowman, 2003; Zanella et al. 2002).

Misue, Eandes, Lai and Sugiyama (1995) recommended maintaining the users' mental map by using a right set of orthogonality, proximity and topology principles to improve current fisheye structures. In order to achieve that, vertical and horizontal grid ordering; distance between objects and hidden topological relationships need to be preserved accordingly.

Also, Gutwin (2002) proposed a technique called *Speed-Coupled Flattening* (SCF) to overcome focus-targeting problems caused by distortion views. This approach dynamically adjusts the distortion level based on the pointer velocity and acceleration. When these two factors are high, the focal distortion will be decreased and flattened to assist user in selecting desired data items. In this study, Gutwin concluded that SCF had significantly improved focus-targeting performance by reducing targeting time and errors, compared with the conventional fisheye distortion views.

Besides that, auxiliary indicator of scale can be used in ZUI to help users keep track of selected views (Furnas, 2006).

CONCLUSION

Due to the context-specific nature of fisheye techniques, their suitability relies primarily on the circumstances of tasks. Thus, this paper is unable to sum up and generalise one "perfect way" to implement such strategies. Instead, what it focuses are the decompositions of fisheye methodology and how they can be tailored to satisfy certain domain goals. In this paper, the concept of focus and context has been highlighted in the visualization of complex information worlds. It has presented FE-DOI subsets and explored their implementation techniques to demonstrate how fisheye view is achieved, along with their respective tradeoffs and extensions. In addition, many related studies have been reviewed to exhibit the adaptations of FE-DOI subsets in generating various fisheye designs. Finally, the usability and practicalities of fisheye techniques in several environments are reiterated, followed by a set of proposed enhancements to improve the current fisheye techniques.

FUTURE RESEARCH

Despite there are existing notational formulations that signify variations of fisheye interfaces, a conceptual generalisation of effective fisheye design techniques is what we need. Therefore, core focus of future researches should lie upon what constitutes a good fisheye layout and the underlying factors that allow its utilization by diverse users.

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