

Initial Explorations into the User Experience of 3D File Browsing

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ABSTRACT

We present an initial exploration into the usability of 3D file browsing. To explore the 3D file browsing technique design space, we analyzed the existing literature and developed three representative 3D file browsing techniques that cover many of their characteristics. Block3D uses a priority weighting scheme to elevate and display files in a grid-based structure. Cluster3D uses sets of animated racks to display files. LTreeCube3D visualizes files and directories using groups of semi-transparent cubes within a larger cube-like structure. We conducted an experiment exploring the affect these 3D file browsing technique have on users in a manual file searching task. Our evaluation is based on task completion time and a post-questionnaire used to gather subjective feedback on each technique in terms of user preference. The results indicate that users completed the manual file search task significantly faster using Block3D than both LTreeCube3D and Cluster3D. Although subjective ranking showed users preferred the Block3D technique, user feedback also showed merits of the other techniques.

Categories and Subject Descriptors

H.5.2 [Information Interfaces and Presentation]: User Interfaces-Evaluation/Methodology

Keywords

3D file browsing, user study, desktop interfaces

1. INTRODUCTION

The public's fascination with 3D and 2.5D desktop interfaces is manifest in the fanciful interfaces of Hollywood and positive reactions to such 3D effects as raised buttons, shadows, reflections and see-through windows. The pervasiveness of this trend is shown by the adoption of these effects in Microsoft's Vista, Apple's OSX and various window managers such as Compiz Fusion. Other desktop interfaces have taken 3D interaction effects to the extreme such as Sun's Project Looking Glass, Hamar's SphereXP and Croquet [20]. While it is easy to dismiss these effects as "eye-candy" or merely

an advanced visual presentation, other work [13] suggests that positive experiences will improve user performance. As such, interface techniques should be designed as much for their efficiency as their affect, as both impact overall user performance.

Understanding the design of 3D file browsing techniques is not as simple as their 2D desktop counterparts. While 3D has the potential to increase the accessible area, incorporate user's naive understanding of physics, and increase affect, 3D also presents entirely new ways to impede user performance and increase disorientation. As a simple example, to select an icon in 3D requires positioning not just along the width and height of a 2D icon, but in depth as well. Additionally, development complexity increases when using a 3rd dimension, requiring a large performance gain to justify the added development time and expense. The 2D windows, icons, menus and pointer metaphor (WIMP) [5] has dominated the desktop interfaces for decades and for good reason.

This work is the beginning of a project to understand the trade-offs and synergy between efficiency and affect on the task of 3D file browsing. File browsing was chosen because of the ubiquity of search in nearly all interfaces and thus a wide applicability of these results. Our goal is to organize the design characteristics, understand how these characteristics can be used to design interfaces, and the characteristics' effect on efficiency, measured by timing, and affect, measured by user preference. While there have been numerous studies of 3D techniques for file browsing, their focus has been on efficiency over affect as opposed to the more ecologically valid measure of overall performance.

In the next section, we present a review of 3D file browsing techniques. In Section 3, we describe three file browsing techniques used in this preliminary study. In Section 4, we describe our experimental comparison of the techniques. Section 5 discusses the results and we end with future work 6 and conclusions 7.

2. RELATED WORK

2.1 3D Browsing Metaphors and Techniques

Several metaphors have been used for desktop 3D browsing. The Data Mountain [17] laid out web pages as if on an uphill slope, with less visited pages higher-up. Microsoft's Task Gallery [18] used a room metaphor, stacking applications along walls in a series of rooms. SphereXP [10], a commercial desktop application, attaches content to a sphere which can be rotated to explore the data.

Several techniques have also been used for desktop 3D browsing. TreeCube [21] is a 3D version of TreeMap [19] that renders all content simultaneously in a semi-transparent cube. As the user searches, smaller cubes are extracted from the larger cube. Baumgartner's file browsing technique [3] combines 2D and 3D interaction. Tactile3D [12] is a commercial 3D desktop environment,

rendering folders in nested spheres. Dengel [8] developed a variety of 3D file browsing techniques to visualize the results of queries, such as laying out files at different depths in a plane, PlaneMode, and in clusters of similar files, ClusterMode.

Some existing 2D visualization techniques have been successful by incorporating 3D properties. This includes Zoomable User Interfaces, such as Pad++ [4], that allow users access to progressively detailed information, following the zooming metaphor. Focus Plus Context [2] uses different levels of detail to allow focus on data specifics while still providing the context of data, such as by fish-eye lens [9].

2.2 Comparison Evaluations to 2D Browsing

Past evaluations comparing 2D and 3D browsing techniques have returned mixed results. Ridsen [16] compared two 2D techniques, a collapsible tree browser and a category based browser, against one 3D technique, a hyperbolic tree graph structure called 3DXML. While 3DXML was faster when interacting with existing data, it lost its advantage when managing new or added categorical data. Users held a slight but insignificant preference towards the 2D interfaces. Data Mountain [17] allowed users to manually arrange web pages to better incorporate user's memory. The results found both performance and preference favored Data Mountain over Internet Explorer 4. Zhua and Chen [23] studied 3D file browsing interfaces for delivering spatial knowledge, comparing 2D and 3D versions of different visual elements such as aerial photos and semantic maps. They found that for most combinations, the 3D version was at least as effective, if not more, than its 2D counterpart. Cockburn and McKenzie [7] compared file search in 2D, 2.5D, and 3D environments. Their comparison resulted in decreased file search times as the dimensions increased. Tavanti and Lind [22] performed a similar study where they developed 2D and 3D techniques for browsing. They concluded that the 3D form provided a spatial memory of the files that made file access faster than 2D. Cockburn [6] revisited and re-performed Tavanti's study, with the exception of incorporating overlap in the file elements and perspective effects. After which, Cockburn found no significant difference between the 2D and 3D techniques.

2.3 Characteristics of 3D File Browsers

Based on the literature, we have found common features shared by a variety of different techniques. Five characteristics were identified: color coding, thumbnails, camera focus, animation, and grid layout. First, color coding was applied by either user prerogative [3], by category [23] or as an indicator of file statistics [8]. Second, thumbnails were used by most techniques as a preview [3, 8, 10, 17, 18, 21], being either user [3] or automatically [8, 18] placed. Third, most techniques that used a hierarchical arrangement of folders, display only the current folder's children. To access files and folders inside a folder, the folder must be activated, placing the camera's focus on the folder. This is all similar to a 2D WIMP interface. Fourth, animation was used to show actions such as movement or task switching [15, 17, 18] or to show more information such as the spinning thumbnails of ClusterMode [8]. Many of the reported techniques do not use hierarchical browsing so have not explored animation's design potential. Consequentially, only a few techniques have explored how to present children in a hierarchy. TreeCube [21] is an exception, using animation to pull apart the cube, uncovering occluding thumbnails in the process. Lastly, layout was varied between using 2D grid layouts with varying height [3, 8, 12] or clustering. As clustering can lead to overlap, ClusterMode's spinning racks [8] can present more information in the same space.

3. FILE BROWSING TECHNIQUES

To explore the design space, containing the features described above, we chose to keep two features constant, color coding and thumbnails, and to vary camera focus, animation, and grid layout. We derived the techniques such that each one excluded one of the three variable features. In this way, the techniques' design-spaces remained large while it remained possible to control for each characteristic. As such, we implemented Block3D, based on Dengel's PlaneMode [8], Cluster3D, based on Dengel's ClusterMode [8], and LTreeCube3D, based on Rekimoto and Green's TreeCube [15]. These are shown in Table 1.

	Block3D	Cluster3D	LTreeCube3D
Animation	No	Yes	Yes
Grid	Yes	No	Yes
Camera Focus	Yes	Yes	No

Table 1: Key characteristics for the selected 3D file browsing techniques. Animation refers to the implementation of animations in active file browsing. Grid implies placing the files in a grid layout. Camera focus refers to the focus of the virtual camera only on the current folder.

3.1 Common Elements

Effort was made to keep the three techniques consistent. All techniques render a file thumbnail with the name of the file below it. All thumbnails initially face the user but the user can maneuver around the thumbnails using the arrow keys, as well as zoom in and out. Thumbnails were also contextually relevant to the file name and the folder the file was placed in. For example, the thumbnail of math.doc within a schoolwork folder may contain handwritten equations. When entering a folder, the current folder moves to the left and the new folder is brought into the center of focus, similar to Tanaka's folder-shifting animations [15]. For the grid views, the thumbnail layout could be ordered alphabetically, by file size, by file type, etc.

To avoid biasing the user's search, a random ranking from 1-10 was applied to each file with a folder having the weighted average of all its children. This rank is represented visually as a color ranging from blue to red on a square behind the thumbnail. File layout could be done through many means such as file name, last recently used, most frequently used, file size, etc. Using a numerical scheme with 10 being a very important file, and one representing a file of little importance was used for simplicity.

3.2 Block3D

The Block3D technique (shown in Figure 1) was based on Dengel's PlaneMode technique [8]. Block3D arranges thumbnails on a planar surface, maximizing the viewing area. As such, it is the technique closest to most 2D file browsers but differs in that thumbnails are ordered by and given a height dimension based upon the file's numerical ranking. In this way, the Block3D design explores the use of a grid layout and a camera focus on the current thumbnails but has no animation.

3.3 Cluster3D

The Cluster3D technique (shown in Figure 2) was based upon Dengel's ClusterMode technique [8]. Cluster3D uses multiple spinning racks of thumbnails, clustered by each file's numerical ranking. The spinning racks were animated to look like a page turning in a book so the user could clearly see the new thumbnail rising,

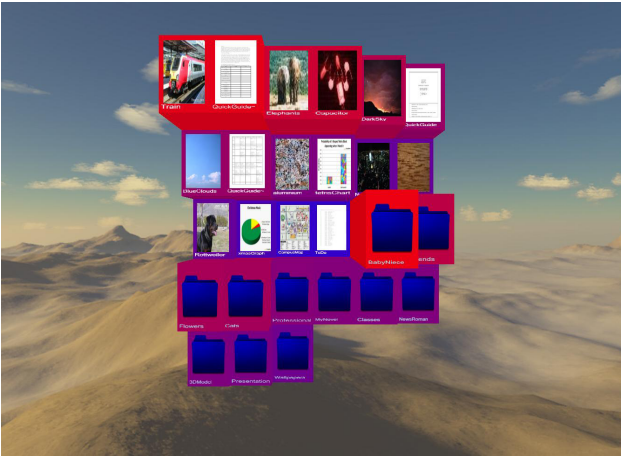


Figure 1: A screenshot of the Block3D file browsing technique.

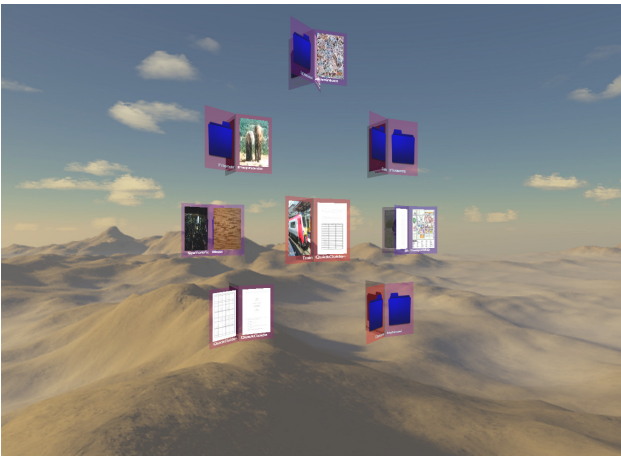


Figure 2: A screenshot of the Cluster3D file browsing technique.

the old thumbnail shifting to the side and with the understanding that all other thumbnails are behind in the rack. The spinning was at first a constant rotational animation, like an airport's baggage claim, but pilot studies showed users disliked the lack of control. As a result, users were given a button to control the animation. In this way, the Cluster3D design explores the use of animation and camera focus but no grid layout.

One issue, and unclear from Dengel's work, was the number of thumbnails per rack. Fewer thumbnails mean faster search and access times but more thumbnails allowed for more dense packing. Also, pilot studies showed a strategy employed by users was to attend to a few racks at a time while they flipped, *eliminating* them from their search. This strategy was problematic if the number of items in the racks differed as, for example, if two racks were being searched and had three and five thumbnails respectively. In this case, the user would flip the racks three times, see the original thumbnail in the 1st rack and assume they *eliminated* the racks from their search. As such, each rack in a folder, except for the last, had the same number of files.

3.4 LTreeCube3D

The LTreeCube3D technique (shown in Figure 3) was based upon the techniques of [14, 15]. LTreeCube3D renders thumbnails

and folders as a collection of transparent and encompassing cubes, as implemented in Okajima and Okada's quantum cube layout [14]. In each cube, the thumbnails are laid out along a grid. The two most important points of this technique are that all thumbnails are shown and that the cube unfolds as folders are opened. Because our pilot testing found the occlusion to be a very strong issue, the folder names are displayed along the cube and are directly navigable. Additionally, we added an animation such that the user could click to unwrap layers of the current folder, moving the layer to face the user and then to the side on another click, pulling up another layer as shown in Figure 3. In this way, the LTreeCube3D design explores the use of animation and a grid but no camera focus.

4. USABILITY EVALUATION

A formal user evaluation compared the three techniques above in a document and image file browsing task. We focused on task completion times and user preference per technique.

4.1 Anticipated Results

Block3D is a technique most resembling traditional 2D interfaces due to its grid layout and lack of animation. We expect that Block3D will result in moderate task completion times and user preferences due to this familiarity. Additionally, document searches we expect to perform better and be more preferred because of the better viewing of the grid layout.

Cluster3D is expected to limit the participant's view, hiding thumbnails in the racks. While this does save space, the current testing does not have folders full enough to truly show this benefit, requiring more effort on the subject to browse through an individual folder. As such, we expect this to have the slowest completion times and be the least preferred.

LTreeCube3D renders all thumbnails, a large advantage, but the overlap may reduce this benefit. However, the partial overlap may be enough for images to be recognizable. As such, we believe this technique will excel at image and mixed document and image thumbnail browsing.

4.2 Participants and Apparatus

Eighteen participants (11 male, 7 female) were recruited from the student population at the University of Central Florida with ages ranging from 18 to 38 in disciplines ranging from Journalism to Computer Science. Of the 18 participants, five have had prior experience with 3D user interfaces, with the most common being simulations and Compiz-fusion [1]. All but one participant played video games. The experiment took each participant approximately 60 minutes to complete and all participants were paid 10 dollars for their time. The experimental setup consisted of a 50 inch Samsung DLP monitor and a desktop PC with a 2.4 GHz quad-core processor and a Nvidia 8500 graphics card running Windows Vista (see Figure 4).

4.3 Experimental Task

Users were asked to find a target file, given a thumbnail view of the file, using one of the techniques above on a folder tree. There are three different folder trees, each containing three different types of files: documents, images, and a mix of both.

Participants had the following cues (independent of file browsing technique) for searching:

- File Name: The name is associated contextually to the folder it belongs to, so files named "ClassAssignment" would be under the "Classes" folder.
- Image Thumbnail.



Figure 3: A screenshot of the LTreeCube3D file browsing technique.



Figure 4: A user participating in the experiment with L-TreeCube3D shown. On the left-hand side of the screen, the target image is shown.

- Ranking and its associated color.

4.4 Experimental Design and Procedure

We used a 3x3 within subjects factorial design, where the independent variables are file browsing technique and file type. The dependent variable was task completion time, measured by the time between displaying the target thumbnail and the participant clicking on the target. Four search tasks were made per condition, resulting in 36 total trials.

The experiment began with a consent form and a pre-questionnaire that asks for a participant's gender, age, experiences with file browsing, 3D user interfaces, and video games; specifically the types of games played and for how many hours a week. Participants were shown the types of cues used to find files and the contents of all three folder trees using a tree diagram. Then participants went through a practice session lasting about five minutes, where they searched for files using each file browsing technique. Participants then proceeded with the experiment. Target files were randomly selected with a bias for more highly ranked files. No file was searched for twice during the experiment. The experiment concluded with a post-questionnaire. For each file type (images, documents, and mixed), participants were asked to choose which 3D file browsing technique was preferred the most, the least, and why. Participants were also given the opportunity to provide any comments that had for each technique.

4.5 Results

4.5.1 Task Completion Time

A repeated measures two-way analysis of variance (ANOVA) was performed on the dependent variable, task completion time. The independent variables were 3D file browsing technique (BT) and file type (FT). Table 2 summarizes the main effects for both independent variables and their interaction. Significant effects were found for both independent variables, but not their interaction.

Effect	Task Completion Time
BT	$F_{2,16} = 15.42$ $p < 0.05$
FT	$F_{2,16} = 7.84$ $p < 0.05$
BT \times FT	$F_{4,14} = 1.51$ $p = 0.21$

Table 2: The main and interaction effects for browsing technique (BT) and file type (FT) for task completion time.

To gain a better understanding of how the different conditions affected task completion time, we conducted a post-hoc analysis, performing pairwise comparisons on the three BT (three comparisons) and on the three FT (three comparisons). To control for the chance of Type I errors, we used Holm's sequential Bonferroni adjustment [11] with three comparisons at $\alpha = 0.05$ for each test.

	Block3D	Cluster3D	LTreeCube3D
Mean:	15.34s	19.28s	21.05s
SD:	4.41s	5.43s	4.66s

Table 3: Mean completion times (in seconds) for the three file browsing techniques when file type is collapsed.

For BT, (see Table 3), there were significant differences between Block3D and LTreeCube3D ($t_{17} = -5.16, p < 0.0083$) and Block3D and Cluster3D ($t_{17} = -3.78, p < 0.01$). There was no significance between Cluster3D and LTreeCube3D ($t_{17} = -1.59, p = 0.131$). These results indicate that participants performed significantly faster with Block3D than with either Cluster3D or LTreeCube3D.

For FT (see Table 4), there were significant differences between Images and Documents ($t_{17} = 3.91, p < .0083$) and Images and Mixed ($t_{17} = -3.09, p < 0.01$). There was no significant difference between Documents and Mixed ($t_{17} = 0.18, p = 0.857$). The

	Images	Documents	Mixed
Mean:	15.34s	20.19s	19.95s
SD:	3.91s	4.94s	6.52s

Table 4: Mean completion times (in seconds) for the three file types when file browsing technique is collapsed.

results imply that participants were able to search for images significantly faster than documents or the combination of images and documents.

4.5.2 Post-Questionnaire Results

For each file type (documents, images, and mixed) we asked participants to select which technique they preferred the most and the least. The results from the most preferred data are shown in Figure 5. Chi-squared analysis of the data revealed that the Block3D technique was significantly favored ($\chi^2_2 = 6.33, p < 0.05$) as the most preferred technique when searching for documents.

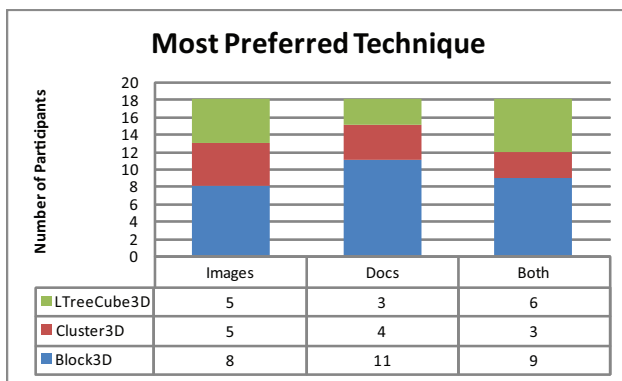


Figure 5: The number of participants who most preferred each 3D file browsing technique for each file type.

We also analyzed general trends in the reasoning behind why participants chose their most and least preferred browsing technique. We found several themes in the comments for each respective technique. For Block3D, the most frequent comments made, from those who preferred it, was its ease of navigation and file organization for all three file types. One participant said, "It was easier to control and the files were neatly organized." A few participants noticed the similarities between this technique and traditional 2D interfaces. For those participants who least favored this technique, their predominant comment was that it was tiresome and overwhelming.

Those who most preferred Cluster3D claimed it was easy to use, whether navigating or finding files, had a fast pace, and enjoyed the flip animation and the spacing. One participant noted, "Flipping through files provided encouraging visual feedback. The way all the files were spread out made the task of searching for a specific document easier." Those participants who favored this technique the least did not like the animation and felt the technique obscured objects.

Participants who preferred LTreeCube3D found it made searching easy. A participant wrote, "I was able to see all the files at the same time. It helped to have everything all at once." Some participants found the ability to have all of the files in one place to be useful, a quality unique to this technique. The most negative comments in relation to this technique was that it had a poor organization, a slow speed, and gave an overwhelming feeling.

5. DISCUSSION

The Block3D technique was a familiar interface to users. This familiarity may explain why this technique significantly performed the best in the task completion times. The most often mentioned comment was the ease of navigation. As expected, Block3D was significantly the most preferred technique for documents.

The Cluster3D was not the worst or slowest technique as expected. The technique did not perform as well as Block3D, as indicated by task completion times, but did not seem to suffer as badly as LTreeCube3D when compared to document preference data. Cluster3D's completion times, though not significant, indicated that it was not the slowest technique. A more surprising result was that the participants commented that they liked the spacing between the groups, not necessarily the grouping characteristic that generated the spacing.

LTreeCube3D's task completion times were the slowest, though not significantly different than Cluster3D. LTreeCube3D was the least preferred and the most disliked technique, though not significant. The qualitative data showed feelings of being overwhelmed, resulting from the technique's showing of all files at once in a cube. Rendering speed of all files may also explain the technique's slower feel. Because of the slowness and user's sentiments, along with the poor task completion times, the characteristic of showing all files may not be a positive one. Despite these comments, the only technique that was characterized as 'fun' was LTreeCube3D.

Techniques that had animations, LTreeCube3D and Cluster3D, did not seem to provide additional benefits in task completion times and usability preferences, compared to the Block3D. This result implies that additional animations may hinder file searching. However, the usability criteria implies a positive affective response for LTreeCube3D, and Cluster3D. By having affective benefits to the different techniques, we observe benefits to the unique features of both those techniques.

6. FUTURE WORK

From the results of our evaluation, there is a significant amount of work that needs to be done to better determine the efficacy of 3D file browsing techniques before a comparison between traditional 2D browsing techniques and an ideal 3D file browsing technique is conducted. For example, one comment exclusive to the LTreeCube3D technique was a sense of enjoyment. More work is needed to understand the aspects that make this enjoyable. Spacing, one of the noted benefits of Cluster3D, can also be explored for other techniques. Implementation issues may have contributed to the perceived slowness for both Cluster3D and LTreeCube3D. Performing the experiment using a computer with a better graphics card, or switching to a different 3D environment for the implementation, may improve the usability of both LTreeCube3D and Cluster3D.

In terms of scalability, having 3-40 children per folder is a practical cap, but future studies can expand this range. We suspect that whenever the child count is too large for the Block3D browsing technique, the Cluster3D technique, only showing a defined number of files simultaneously, will be more favored by users. For the purposes of this study, we proposed using two differing file types, documents and images. We can expand this list for web pages, audio, videos and animated GIF's, the latter two being a series of images.

The numerical rating system we used was meant to generalize the logical arrangements of files, but the experiment did not allow for any opportunity for the ratings to change dynamically. Introducing new ratings and new data may result in different technique prefer-

ences, and researching different logical arrangement techniques to dictate how the ratings change, would aid in testing this.

One of the factors that was found to speed up file search in a 3D environment, not explored in this initial work, is having the user manually position files. By manually positioning files, the user has the opportunity to form a memory map of the file's individual location[17].

7. CONCLUSIONS

We have presented an experiment that tested three distinct 3D file browsing techniques, Block3D, Cluster3D, and LTreeCube3D. These techniques were chosen based on an analysis of the literature which highlighted important characteristics that shaped this class of browsing techniques. The results indicate that participants were significantly faster in file searching task using Block3D compared to LTreeCube3D and CLuster3D. Participants seemed to find Block3D a more usable technique based in part on its similarity to traditional 2D file browsing interfaces. However, participants did find positive aspects in LTreeCube3D and Cluster3D, namely enjoyment and file spacing respectively. We believe this experiment provides an initial foundation for determining which characteristics are most important for 3D file browsing techniques so true comparisons can be made with their 2D counterparts.

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