Labeling Nodes in 3D Diagrams: Using Transparency for Text Legibility and Node Visibility

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1. Abstract

In scientific and information visualization 3D diagrams are now more common. Text or name labels in any kind of diagram play an important role. In this work we combine both 3D diagrams and text labels by evaluating the legibility of text on 3D shaded diagram elements. The focus is on using a transparent background for the text labels on the nodes. The investigation seeks to determine whether a transparent background for the node labels can result in better readings of the text and nodes in the diagrams. The results show that using a transparent background on the labels can considerably improve text legibility and maintain node visibility.

2. Introduction

Humans resort to drawing diagrams for communicating, planning and problem solving. Diagrams act as cognitive "externalizations" enhancing cognition by mapping problem elements to a visual display in such a way that solutions become immediately evident [10,12]. However, not all mappings are equivalent and a diagram's effectiveness, to some extent, depends on how well it is designed as an input to our visual system [5,11].

We focus our attention on a common class of diagrams called graphs and also sometimes referred to as node-link diagrams. This category of diagrams includes software structure charts [9], entity relationship diagrams, and data flow models. There are many variations of node-link diagrams, but most commonly, the nodes are drawn as rectangular boxes, or circles, and the edges are lines or arrows that connect the nodes. As a generalization, a basic node-link graph can be characterized as having,

- Heterogeneous nodes to represent a variety of different types of entities,
- Heterogeneous edges to represent a variety of different types of relationships,
- Attributes such as labels and color to both the entity nodes and the relationship edges.

We have developed guidelines for effective diagram drawing based on some of the literature on human perception. Particular attention was paid to structural object recognition theory. According to this theory as objects are perceived they are decomposed into 3D set of primitives called geons, together with the skeleton structure connecting them (Figure 1) [1,6].

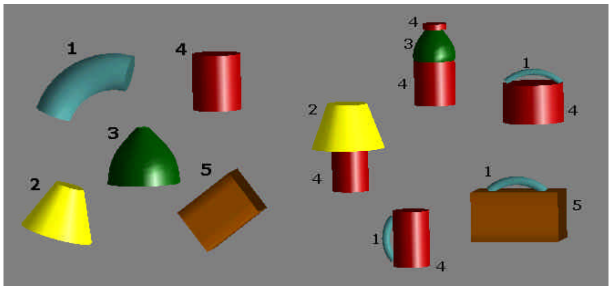


Figure 1. Sample geons and objects made from them.

We conducted three studies in which the effectiveness of using 3D shaped primitives (geons) as components in node-link diagrams were evaluated. The results of the first two studies show that the use of geon primitives in node-link diagrams can result in a improved recall of diagram structure and facilitates faster and less error prone visual parsing compared to traditional node-link diagrams [7,8]. The third study evaluated a series of perceptual semantics and mapped these to semantics found in software modeling diagrams such as UML or ER-diagrams. In the latter study we found that visual representations derived from perceptual principles for object recognition provided stronger cues for deciphering relationships than the traditional cryptic line and box drawings. Our results laid the foundation for what we defined as the "geon diagram". Figure 2 shows a sample geon diagram depicting entities in an academic conference.

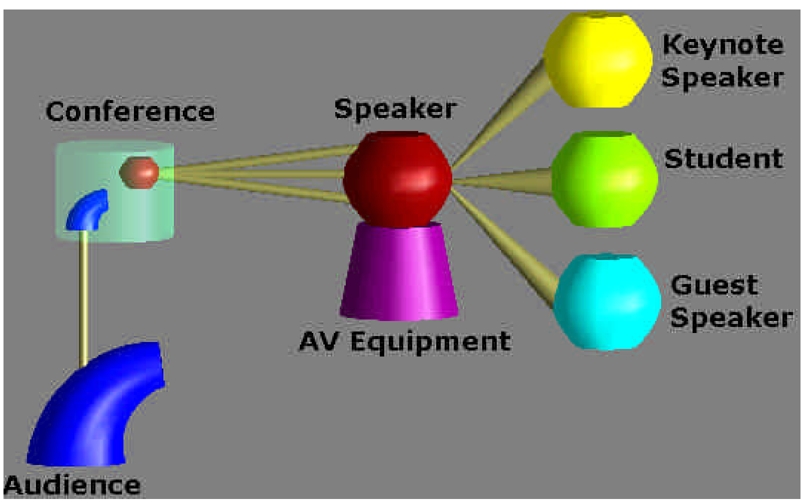


Figure 2. Sample geon diagram depicting entities at a conference. A conference has an audience, has multiple speakers. The speakers are dependent on AV Equipment. There are also different types of speakers represented using same shaped geons.

We have built a toolkit that enables the construction of geon diagrams. However, the toolkit does not have the functionality of labeling the entities in any given diagram (the labels shown in Figure 2 above were added in PhotoShop after capturing the image from the toolkit). The adage a picture is worth a thousand words can be questioned when diagrams are void of labels since they can significantly add information that is not pictorially representable or that would consume valuable real-estate on a screen. Most diagramming techniques use different kinds of labels: captions (description of an image), names (cities for example), or text labels that provide additional information.

This project investigates a proper method for visualizing node labels in 3D diagrams. Although, the study was conducted for the purpose of labeling geon diagrams, the results are applicable to 3D diagrams in general. Three restrictions were formulated to derive an effective labeling technique:

- **Object shape.** Shape of nodes play an important role for visualizing certain semantics In our previous work we have showed that same shaped objects can represent entities of the same kind (such as inheritance). Thus, if we are to label nodes, the distinguishing features of their shape must be clearly visible.
- **Containment.** The semantic of aggregation or composition is best represented via containment. This representation makes use of transparency on a node to show the contained objects. The labeling method used should limit interfering with showing nodes being contained in other nodes.
- **Legibility of text.** Areas of light and dark bands on nodes are created when we apply a shading model to a diagram. As a result, some labels are not clearly readable in certain regions of nodes. The labeling method should therefore consider the legibility of the text as an important criterion in the study.

The first two criteria create the necessary conditions for background visibility while the third criteria emphasizes the importance of text legibility. In the rest of the report, the method for labeling 3D nodes as well as the experiment used for determining the proper labeling style is discussed.

3. Transparent Interfaces

Recently there has been considerable interest in investigating the use of transparency in interfaces. Bier et al. [2] describe a see-through interface based on transparent widgets and filters. Such interfaces increase productivity by reducing steps in a task while providing good graphical feedback. They can also increase performance in multi-modal applications where the user's attention is constantly shifting focus during a given task.

Several studies have investigated the interaction between transparency and text legibility. Harrison and Vicente [3] evaluated the use of transparent menus for navigating within applications. Their motivation was to address the problem of overlapping windows, which obscure needed information when performing a given task. The task involved clicking on target items within a menu. At each trial, the transparency level was controlled at 0% (fully opaque), 50%, 75%, 90%, and 100%. Their study also controlled the type of font used for the text. They used a regular Motif style, Helvetica 14 point font as a Anti-interference (AI-font) font. Their results indicate that visual interference increases as transparency level increases. They also show that high degree of complexity on the background image makes the text less legible.

We apply these results by using a transparent rectangular area around the label; the text of the label is opaque but the area surrounding is transparent. We hypothesized that a semi-transparent background for a label can limit background interference effects with the text while still allowing the user to visually read the background. The rest of the paper is devoted to explaining the experiment we conducted in order to determine the level of transparency required to achieve proper legibility while identifying background material.

4. Evaluation

In order to explore the effectiveness of background transparency of the label, we used a toolkit built for our previous studies. The toolkit allows the creation of diagrams with 3D shaded nodes and edges. We added the capability of inserting text on nodes using OpenGL outline fonts. The toolkit:

- Allows building diagrams from a set of 24 geons,
- Is equipped with geons that can have surface properties such as color, texture, shading, and transparency,
- Provides for metric associations with the use of varying sizes and shapes of objects and their positioning in space,
- Provides for symbolic associations via surface properties,
- Formulates topological associations by the structural composition of geons,
- Enables labeling of the geon primitives.

The ultimate goal of the experiment was to determine whether semi-transparent backgrounds on labels could facilitate better recognition of text on labels and node information. To this end, the experiment consisted of locating a sub-structure of a diagram within a set of diagrams. We recorded the amount of time it takes a subject to recognize a sub-structure as well as the accuracy of the identification. A total of 14 students volunteered as subjects for the experiment.

4.1 Method

Diagrams. We constructed five sets (a,b,c,d,e) of ten diagrams each for a total of fifty diagrams. In each set the sub-structure was only present in half (or five) of the diagrams. The sub-structure at different levels of transparent text background is shown in Figure 3. To identify that the sub-structure is in a diagram, its constituent nodes, node shape and color, as well as label needed to be matched. A simple template match will not suffice as Figure 3 shows the same substructure with a different layout.

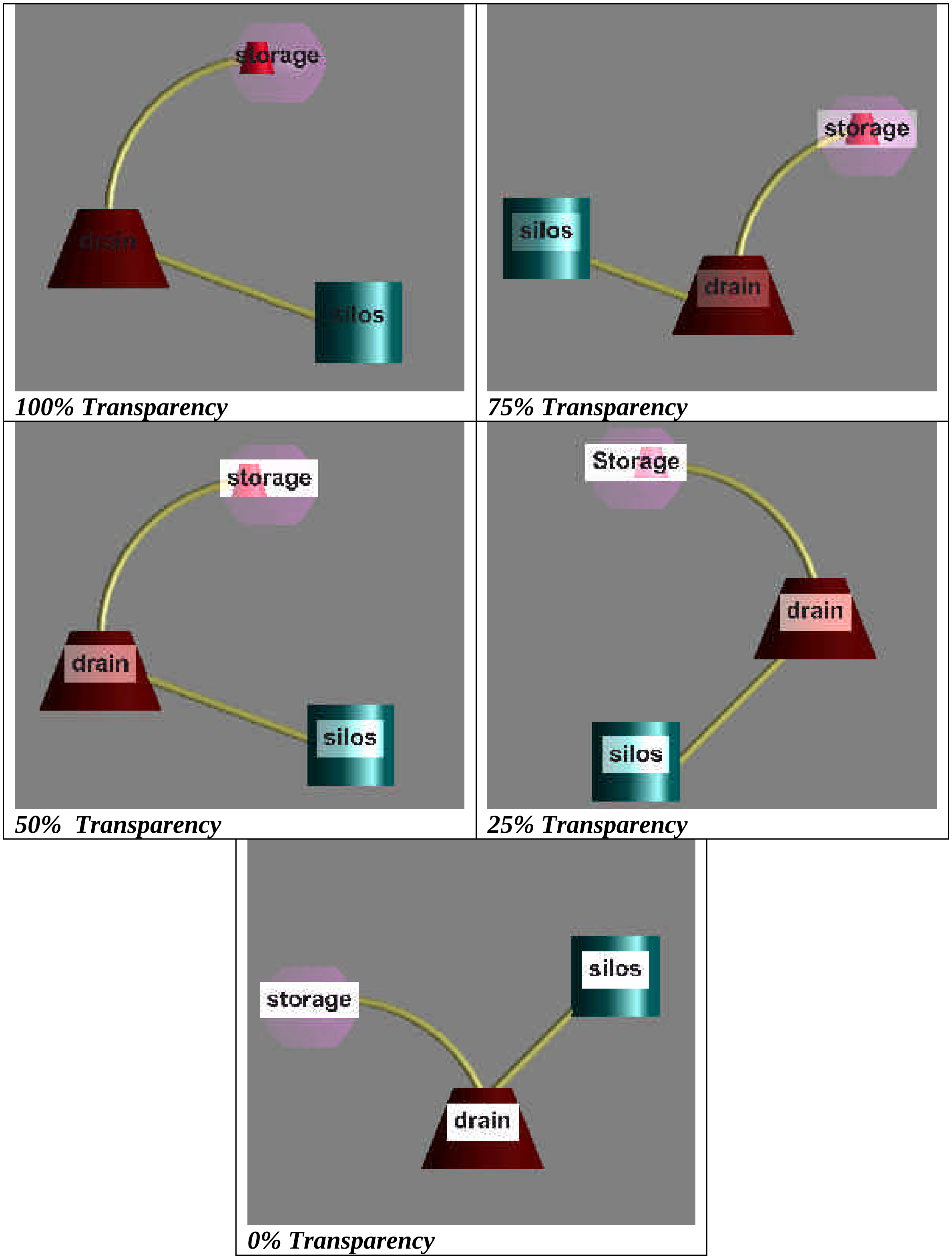


Figure 3. The substructure shown using different levels of transparency for the label's background. Subjects had to match the substructure by identifying the topology (not layout) consisting of the correct shape, color and label for the nodes.

The number of nodes in all fifty diagrams ranged from 10-12 and the number of edges from 9-13. The diagrams did not depict any particular system, but simply consisted of different types of geons with different shades of color and different labels. The text was drawn using Helvetica, point size 14 as in [3]. Closely related names were selected for the nodes as listed in Table 1 below.

drain	rain	Train	brain
storage	storing	Store	shed
silos	soil	Sprinkler	building
garden	gardener	Drainage	drained
water	watering	Pump	well

Table 1. Text labels used for the experiment. Note that very similar labels to those chosen for the target nodes are included in the list.

The diagrams were drawn with the following conventions. If the target substructure was not present in the diagram, then a distracter that closely resembled the substructure was included. Most distracters varied on one or two conditions, such as a different label, color, or shape on one or two of the nodes. A sample diagram with a distracter is depicted in figure 4. The diagrams containing the target also included a distracter.

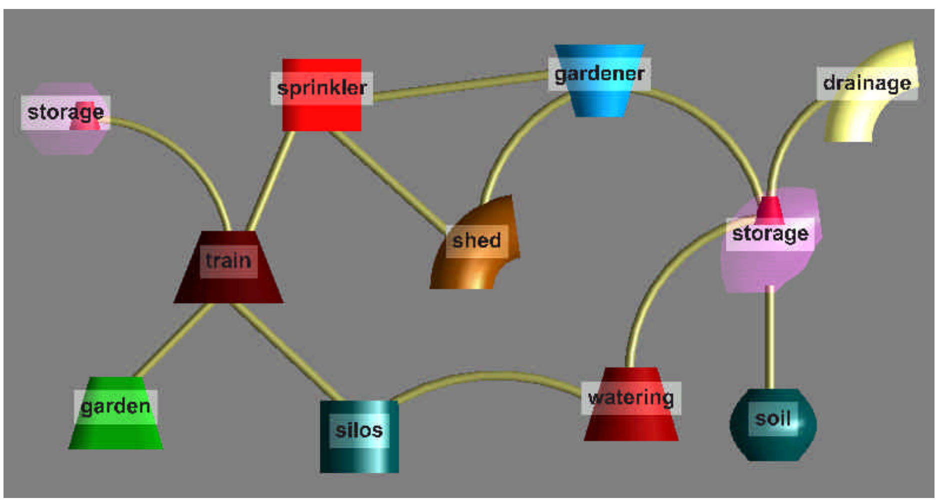


Figure 4. Diagram containing a distracter that closely resembles the target substructure. The node labeled "drain" in the substructure has been modified to "train".

Procedure. The subjects were shown the substructure for 15 seconds at the start of each trial after which they were given four practice trials. The program randomly selected the level of transparency to test for and randomly associated with it one of the 5 sets of diagrams. As a result, the first subject may have performed the experiment in the following order {0%:b,75%:e,50%:c,100%:a,25%:d} while the second subject would perform the experiment in the order {75%:d,100%:b,0%:c,25%:e,50%:a}. For each trial the program selected a diagram randomly from the set of 10 diagrams and presented it to the user. The user pressed the 'Y' key if the sub-structure was present or else pressed the

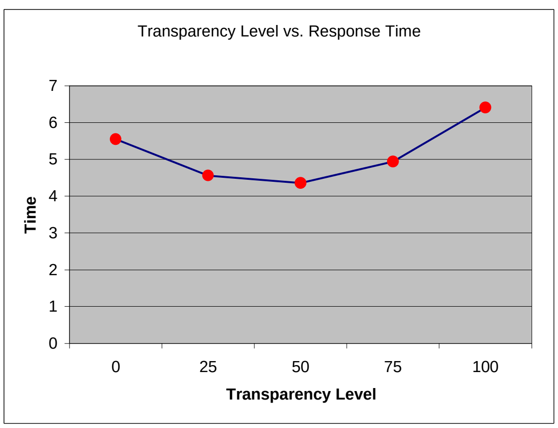
'N' key. The response time of the user was captured along with the accuracy of the response.

4.2 Results

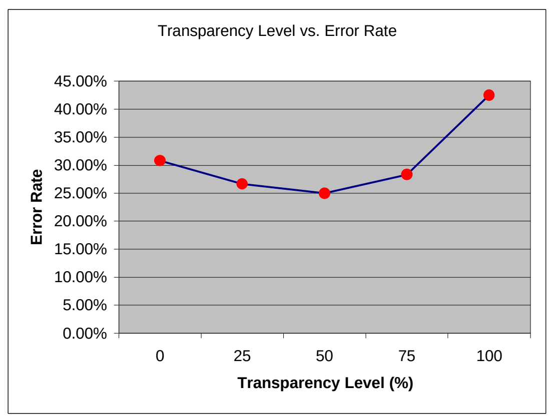
The results are summarized in Table 2 and figure 5. These show that substructures were identified both faster and more accurately when the level of transparency of the labels' background was at 50%. At this level subjects on average took 4.36 seconds to identify (correctly or incorrectly) the presence of the sub-structure in the diagrams with an error rate of 25%. Weakest performance was achieved when the background was 100% transparent and suggests that when the interference effects increase, the legibility of the text is degraded. At the other spectrum (0% transparency) when the label's background is entirely opaque, there does not result any interference for text legibility but at the cost of poor background visibility.

Transparency Level	*0%*	*25%*	*50%*	*75%*	*100%*
Response Time (seconds)	5.55	4.558333	4.360833	4.937833	6.40975
Error Rate (%)	30.83%	26.67%	25.00%	28.33%	42.50%

Table 2. Average response times and accuracy rates for identifying presence of substructure in the diagrams.



a) Average response times



b) Average accuracy rates

Figure 5. Optimal performance is achieved when the label's background is 50% transparent. Performance is degraded at both extremes suggesting that when the label's background is opaque (0% transparency) it takes longer and becomes more error prone to read background information. When the label's background is not existent (100% transparency) larger amounts of interference results in poorer legibility of the text.

An ANOVA procedure was used to investigate how the transparency level, diagram difference, and subject-to-subject differences affected time to respond. The interaction level of subject and transparency (18%) suggests that not any given transparency level is best for everyone. Overall, using transparency is statistically significant (p-value = 0.01). A Tukey's analysis for multiple comparisons shows a significant improvement between the 0% and 50% levels (p-value=0.0377), and a significant improvement in performance between the 25%, 50%, and 75% levels in comparison to the transparency at the 100% level. Thus, the results do not clearly indicate the optimal level of transparency but strongly suggest that using transparency can improve text legibility and node visibility.

5. Conclusions

We evaluated the use of transparent label backgrounds for achieving text legibility and background visibility on nodes in 3D diagrams. A conjunctive search task was developed for the experiment, which tested the subjects' capability of recognizing a substructure based on the text of the substructure and its background information. It was found that users located the substructure faster and with fewer errors when the label's background was 50% transparent. Statistical analysis of the data shows that any level of transparency is adequate for the task and that performance is significantly improved when the label has a transparent background. An extension of this work could investigate the effectiveness of using transparent label backgrounds when nodes are textured.

6. Acknowledgement

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