Visualizing Graphs in Three Dimensions

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Context

Title：Visualizing graphs in three dimensions

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Cited：137

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Background

1. Low display level

2. Visualization in 3D and stereo motion depth cues could support spatial perception

3. Limits in 2D display

Perceptual Issues

Depth Cues:

1. Stereoscopic disparities
2. Kinetic depth
3. Perspective
4. Texture and size gradients.
5. Occlusion
6. Shape from shading.
7. Others – cast shadows, focus, eye convergence

"Depth perception is the visual ability to perceive the world in three dimensions (3D) and the distance of an object."

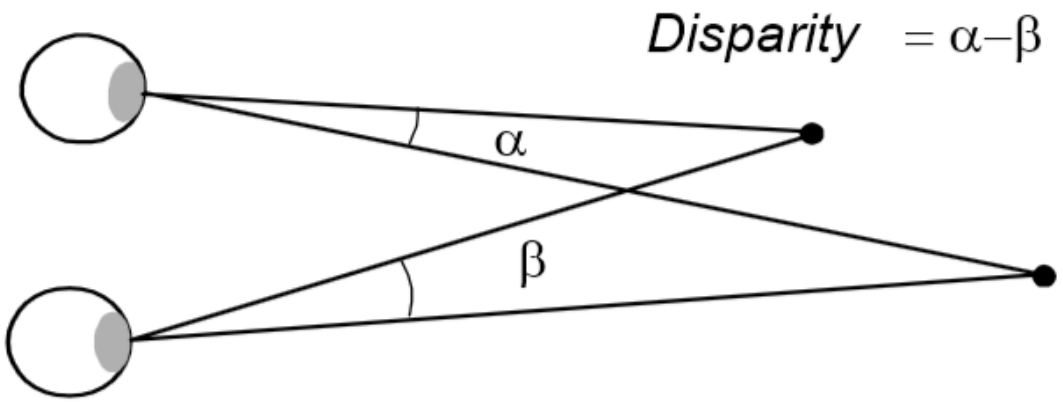
Perceptual Issues

Why the Stereoscopic disparity and kinetic depth are most important?

These are the cues that are most likely to be useful for perceiving 3D graphs and trees hence they have received the most attention from researchers.

Stereoscopic disparity

"Stereoscopic depth relies on the detection of relative differences, called disparities, between pairs of features imaged in the two eyes. "



extraordinarily fine judgments

1. Wavy line——1 arc second
2. Line disparity——12 arc seconds

human visual system： The extreme sensitivity of the to disparities

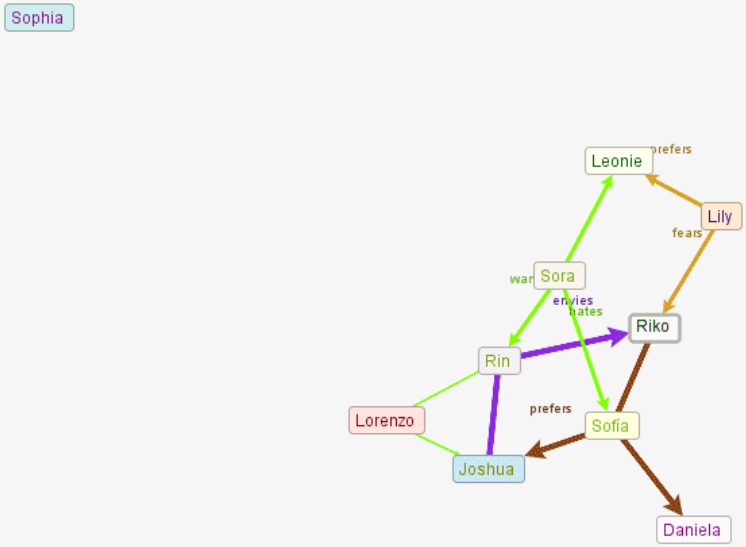
Structure-from-motion cues

kinetic depth effect：

“The projected image of a rotating 3D wire object appears strongly three dimensional, even though when the motion is stopped the object appears completely two dimensional.”

Spring Layout Algorithm

1. represent graph edges as springs
2. connected nodes are pulled together and pushed apart
3. all nodes repel one another according a function that is proportional to the inverse of the distance between them.
4. iterative process until equilibrium



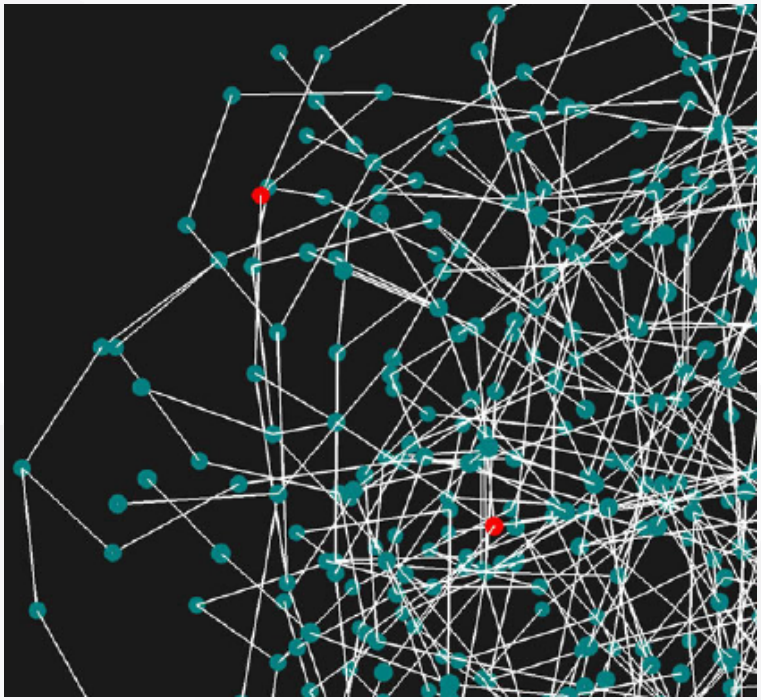
Experiment 1

Spring layout graphs with and without stereo and motion cues

1. Task
2. The Display
3. Conditions
4. The Graphs
5. Participants
6. Procedure
7. Results

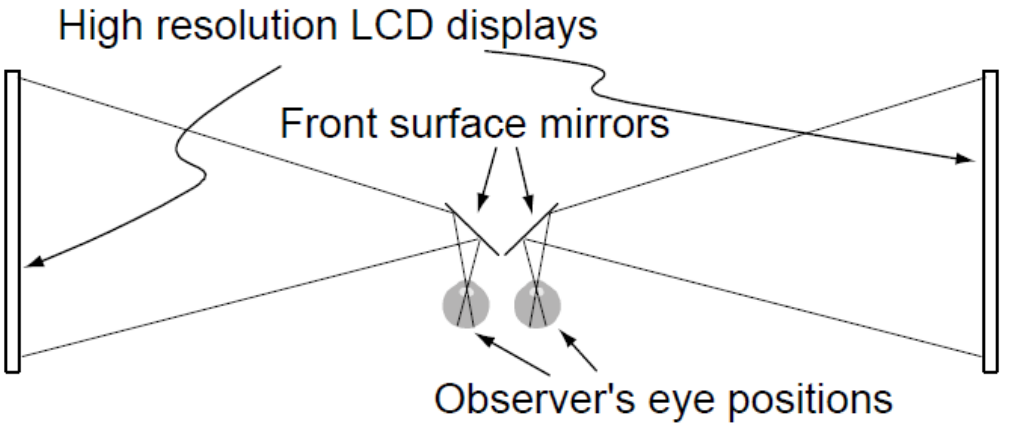
01 Task

On each trial the subject was presented with a graph having two of the nodes highlighted in red. The subject's task was always to determine if the nodes were linked by a path of length 2 or 3.



02 The display

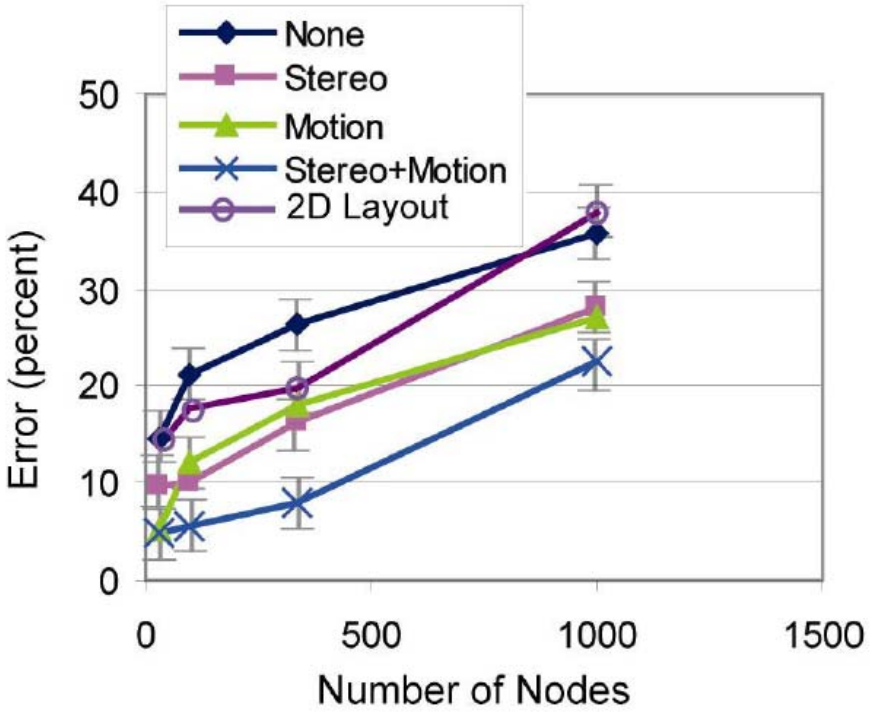
The displays were Viewsonic VP 2290b monitors.
Each of these displays has 3840x2400 pixels.



03 Conditions

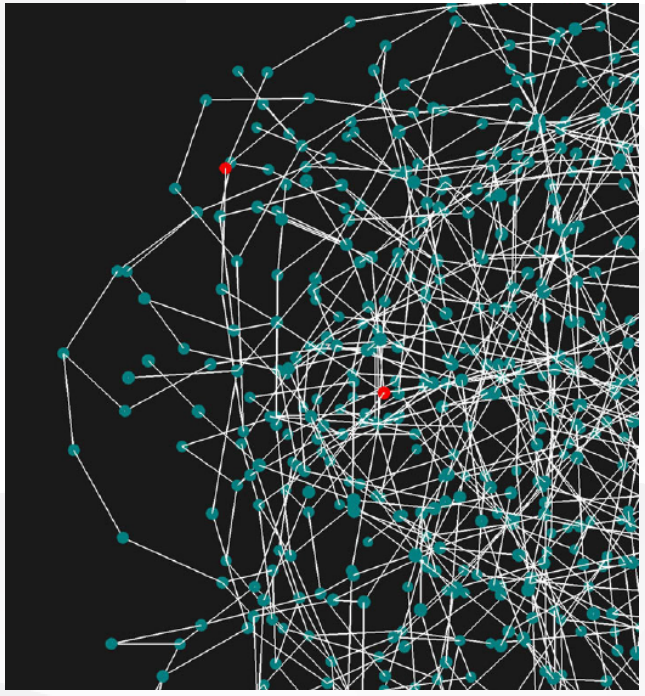
There were four conditions with 3D spring layout of the graph and one with 2D spring layout.

- **No stereo, no motion.** Participants saw a static, non stereo perspective projection of the 3D graph
- **Stereo.** Participants viewed the graphs as a stereo pair generated with an assumed eye separation of 6.4 cm.
- **Motion.** Participants viewed the graph rotating smoothly at a rate of one complete cycle every 36 seconds.
- **Stereo and Motion.** Participants viewed a graph with both stereo and motion cues.
- **2D layout.** The graph was layed out in 2D. This means that there was no occlusion of one node by another.



04 The graph

The algorithm randomly assigned links in such a way that the following statistics resulted (rounded to the nearest integer percentage): 6% of the nodes had degree one (leaf nodes); 37% had degree two; 45% had degree three; 10% had degree four; 2.0% had degree five or greater.



There were three kinds of forces used in the layout:

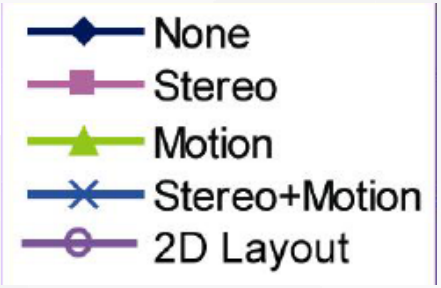
1. Nodes repelled each other
2. Nodes connected by an edge
3. Forces along the x,y,z towards the origin

05 Participants

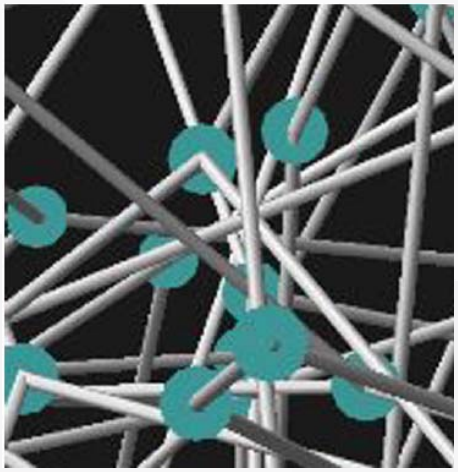
The participants were 15 undergraduate students, paid for participating. In addition, the two authors of this paper also carried out the experiment to get an estimate of performance from more experienced observers.

06 Procedure

The experiment was the product of the 5 viewing conditions with 2 rendering styles and 4 graph sizes, yielding 40 different conditions. Trials were given in blocks of 20 for each condition. The entire set of conditions was randomly ordered.



Lines



3D Tubes

07 Results

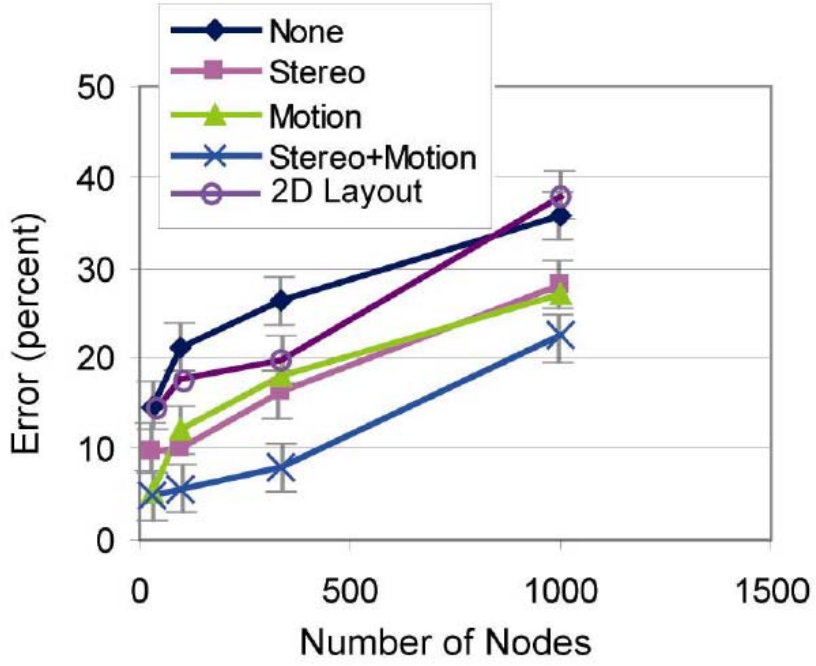


Figure 6. Errors as a function of graph size. Averaged data from 14 inexperienced participants. Standard error bars represent inter subject variation.

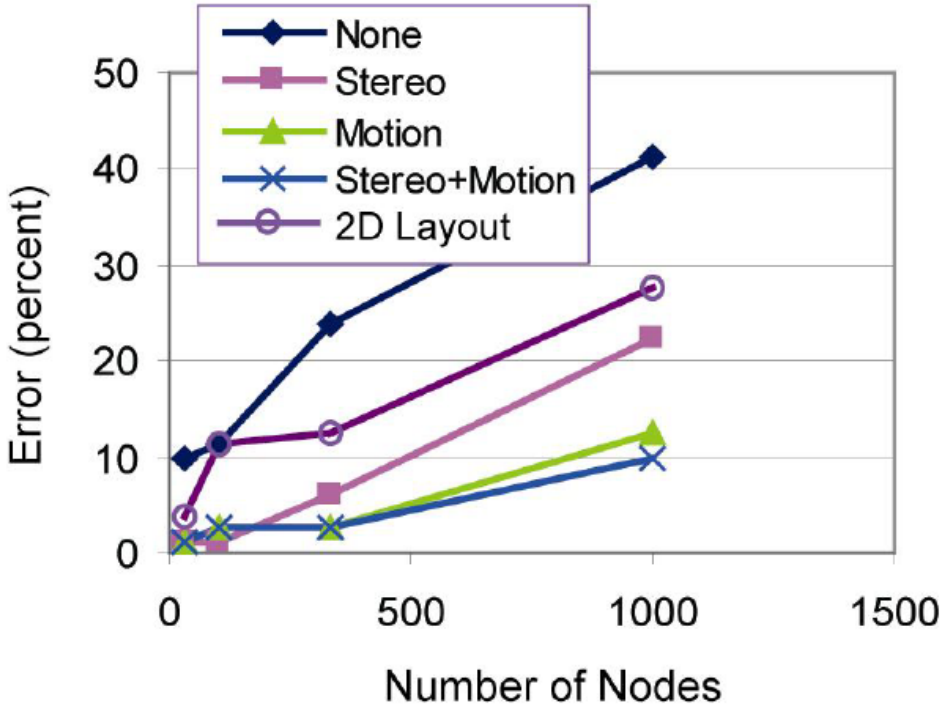


Figure 7. Errors as a function of graph size. Averaged data from 2 experienced participants.

Experiment 2

1. Varying the number of nodes and the number of links

2. In particular, the number of links in a graph may be as or more important than the number of nodes.

3. With our second experiment we varied both the number of nodes and the number of links in the hope of finding some simple function relating these variables to perceptual traceability for 3D graphs.

4. the ratio of links to nodes might be the most critical variable in determining the visual traceability of short paths.

Experiment 2

Methods

1. 9 different graph sizes
2. Algorithm

Layout

1. spring layout algorithm with two modifications
2. Scale the graph
3. Effective use

Result

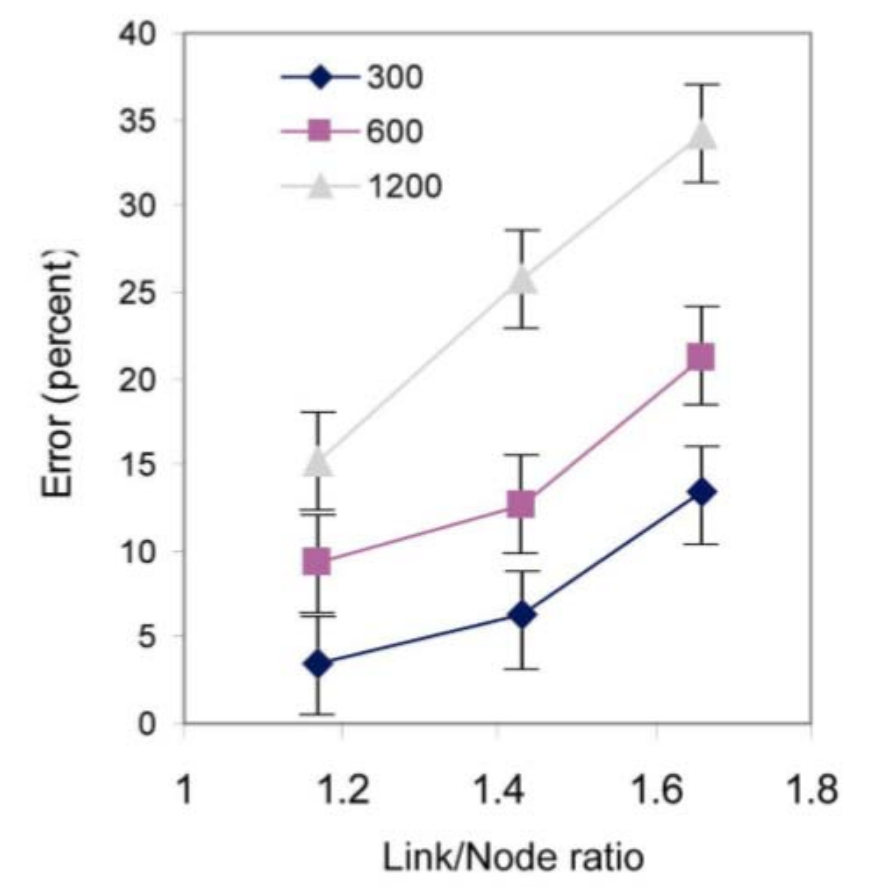
1. Nodes 2. links 3. interaction

Algorithm

n is the number of nodes
rand() returns a random number between zero and one.
dfactor is used to control the edge/node ratio.

```
for(i=0 to n-1)
{
    m = 1
    while (rand() < dfactor)
        m = m+1;
    for (j=0 to m-1) // add m edges to ith node
    {
        insert edge (i,k).
        k is randomly selected
        from the set of node excluding values
        where (i=k) and (i,k) is already in the graph.
    }
}
```

Experiment 2



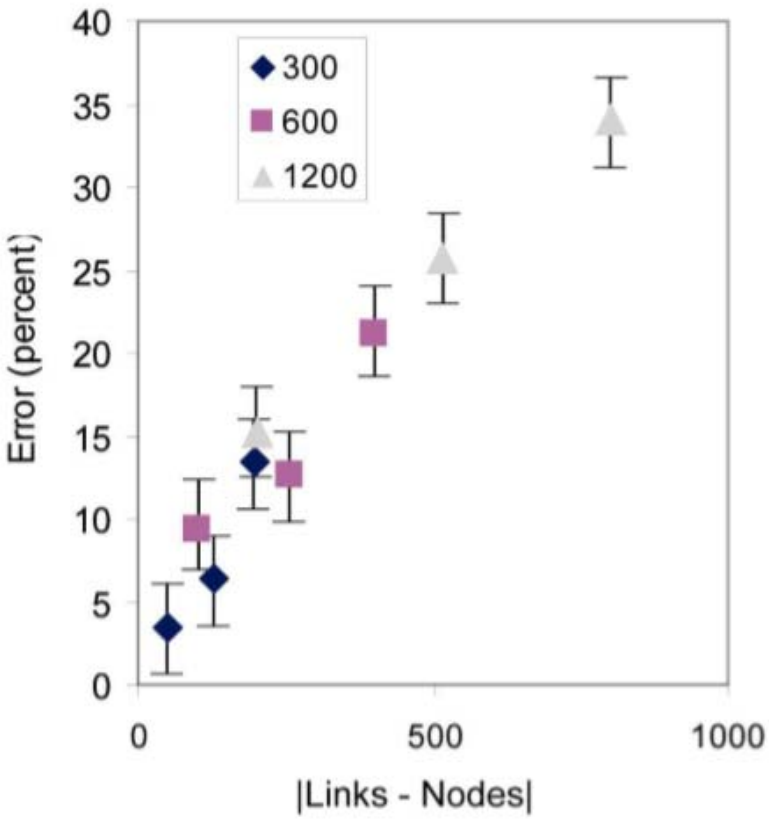
Error rate is plotted against Links/Nodes ratio for the three sizes of graphs.

Cannot approximate a single straight line!

Experiment 2

As can be seen, the result approximates a straight line. If n is the number of nodes and m is the number of links, computing a linear regression through the points yields

$$error = 4 + 0.04(m-n)$$



Mean error rate is plotted against the difference between the number of links and the number of nodes.

Discussion of Experiment 2

1. “the number of links is as important in determining the readability of a graph as the number of nodes.”

2. it is the difference between the number of links and the number of nodes that determines the error rate.

3. Small (or negative) link-node differences would produce low errors, but not negative errors

4. “the curves would be expected to flatten out as the errors approached a chance level of 50%”

Conclusion of Experiment 2

"We found the difference between number of links and number of nodes to best account for error rates and suggest that this is evidence for a "perceptual phase transition"."

Conclusion

Phase change

Graph simplification

Expressing those graphs with low errors

THANKS FOR YOUR ATTETION