TC on Visual Analytics and Communication Tutorial

# Developing aesthetics for graph drawing based on eye tracking

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## Graph

- Graph is a collection of related objects.
- An example: a group of people A, B, C and D:
  - A is a friend of B and C
  - B is a friend of A and C
  - C is a friend of A, B and D
  - D is a friend of C

## Graph visualization

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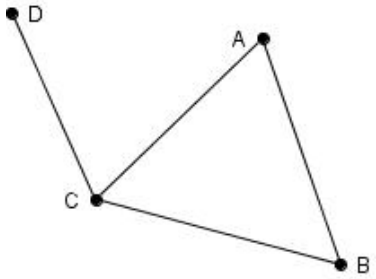


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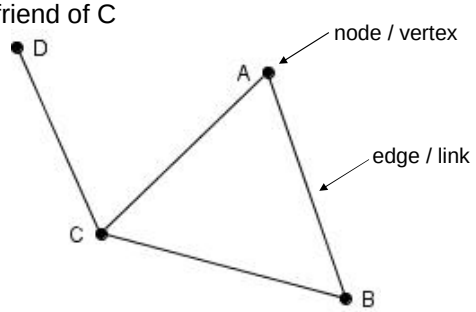

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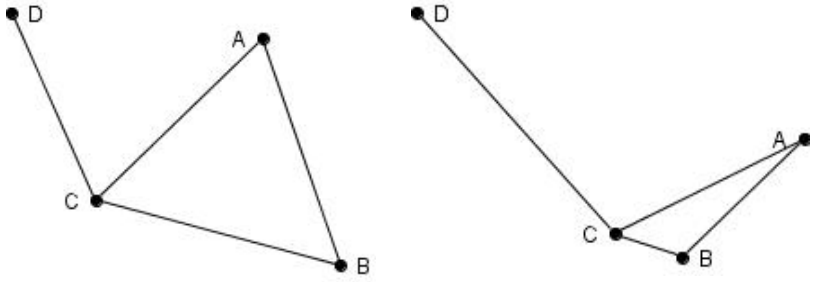


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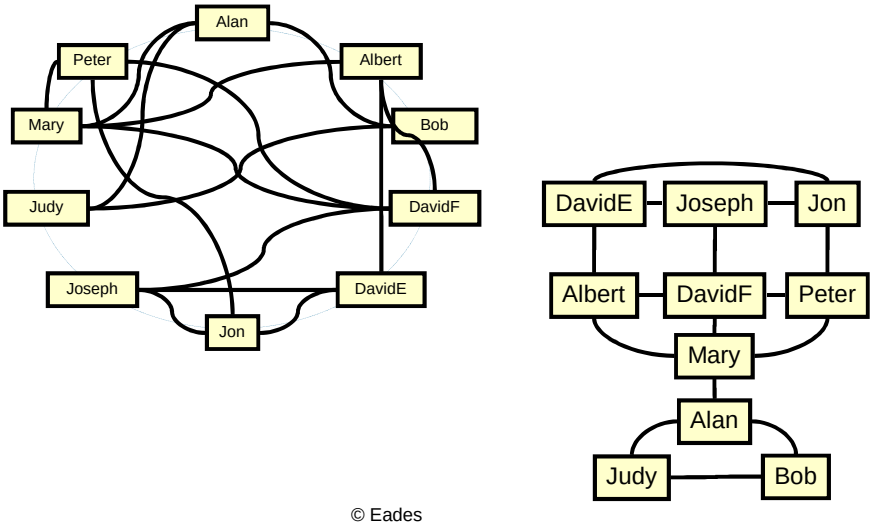


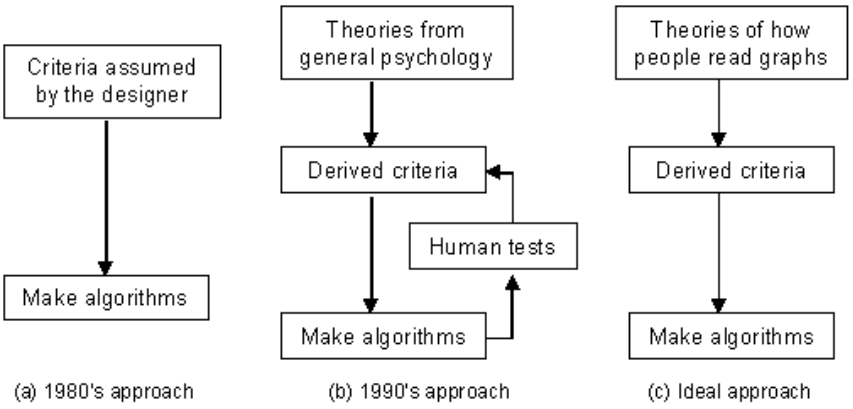
## Evaluation of graph visualizations

- *Performance* has been the main measure of effectiveness in evaluating graph drawings.
- Performance based evaluations have produced some important findings. For example: **edge crossings should be minimised**


## Evaluation of graph visualizations

- Performance measures have limitations
  - Time and error performance logging treat the human as a "black box", which tell us *what*, but not *how* and *why*
- An evaluation can be more useful if more fundamental insights can be obtained:
  - *How* people think, perceive, remember, learn.
  - *Why* performance is better/worse
  - *What heuristic rules* do they use?

## History of graph visualization technology




## Eye tracking: beyond time and error

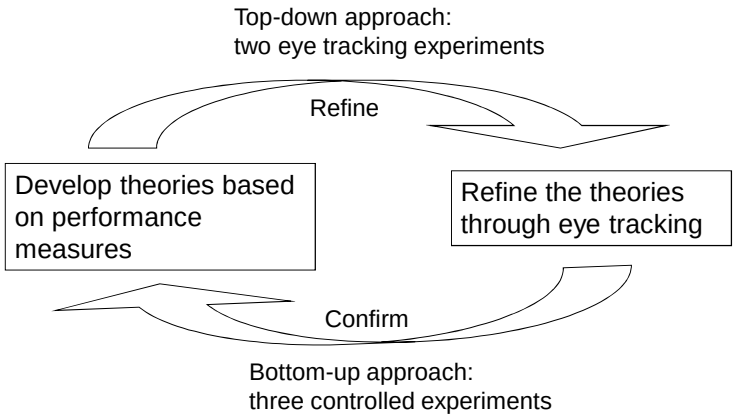
- Where the time is spent and how the performance is affected?
- What is the mechanism of crossings affecting performance?

- Time and error performance logging
  - treat the human as a “black box”, which tell us *what*, but not *how* and *why*

- Eye tracking may give insight as to *how*
- Post-interview and questionnaire tell us *why*

- Two exploratory eye tracking experiments
  - Ex1: small and sparse graphs
  - Ex2: larger and denser graphs
- Three confirmatory controlled experiments
  - Ex3a: existence of geodesic-path tendency
  - Ex3b: effects of geodesic-path tendency
  - Ex4: effects of crossing angles

## Research Methodology

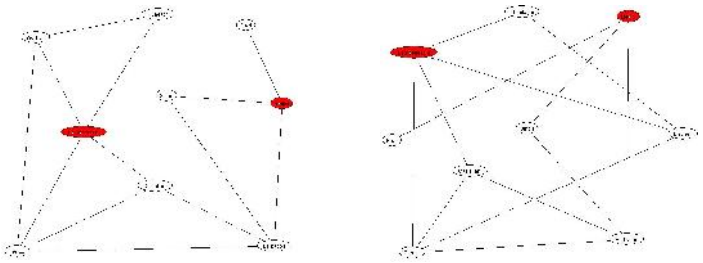


## Eye Tracker

## Experiment 1

- Task: find the shortest path between two highlighted nodes.
- Time, error and eye movements were recorded.
- Questionnaires and interviews.

## Examples of Stimuli

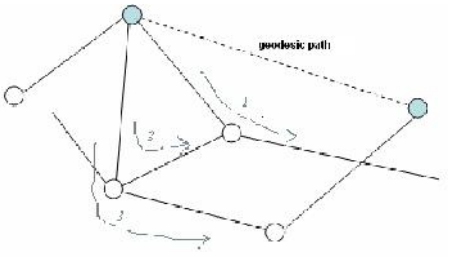


## Results: Time and Error

- Overall,  subjects spent significantly more time with crossing drawings than with non-crossings
- However, on some specific instances, this was not the case

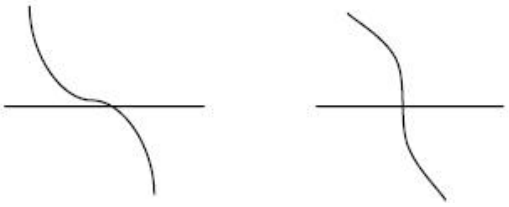
## Results: Eye Tracking Video Data

- Crossings had little impact on eye movements.
- **Geodesic-path tendency**: subjects seemed to follow the geodesic path between the current node and target node.




## Possible Reasons for the Lack of Crossing Effects

- *Crossing angles* may inhibit readability [Ware et al. 2003].

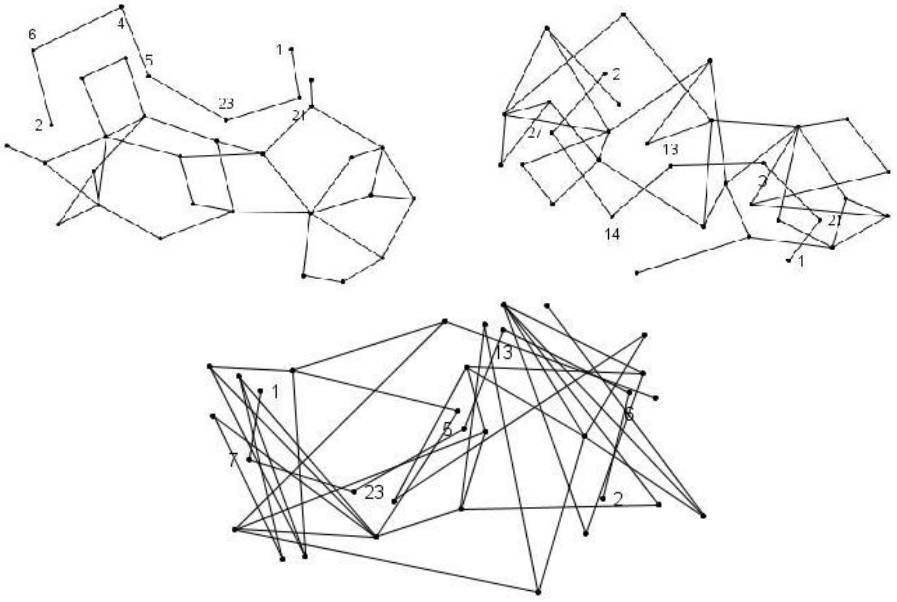


## Experiment 2

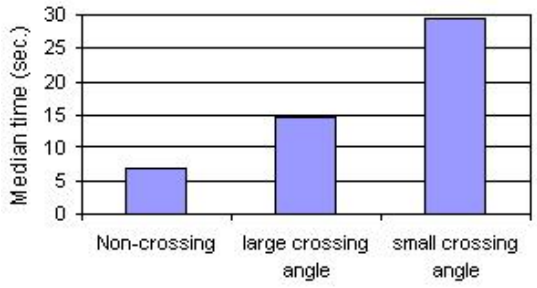
Crossing angle: graphs were drawn with three conditions:

- No crossings on the path
- Small-angle crossings
- Large-angle crossings

## Stimuli



## Results




- Effects of crossing angles were significant on time

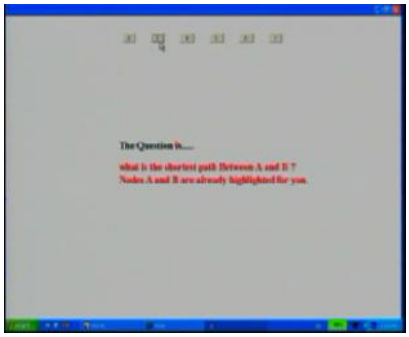
## Results: Eye Tracking Video Data

*No crossings*: eye movements were smooth and fast.

*Large crossing angle*: eye movements were still smooth, but slower.

*Small crossing angle*: eye movements were very slow and no longer smooth (back-forth moves at crossing points).

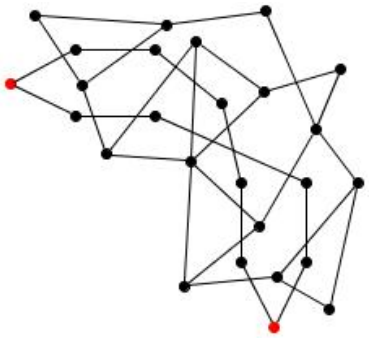
## An Example




- Observations of eye-tracking videos need *confirmation*:
  - Existence of geodesic-path tendency (Ex3a).
  - Effects of geodesic-path tendency (Ex3b).
  - Effects of crossing angles (Ex4).

## Experiment 3a: Existence of geodesic-path tendency

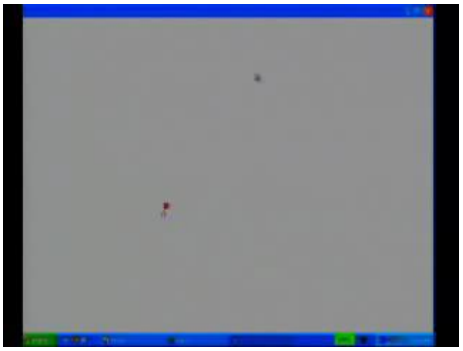
- Two separate paths between the two highlighted nodes



## Results

- Subjects followed geodesic-closest path 75% of the time
- People have a "***geodesic-path tendency***"

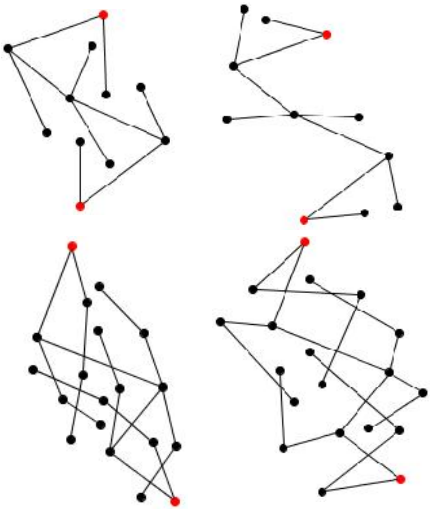
## An Example



## Ex3b: Effects of Geodesic-path Tendency

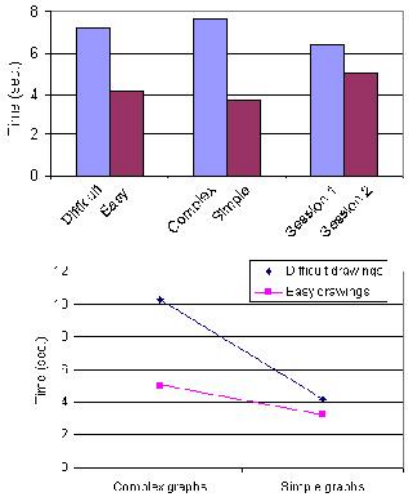
Each graph was drawn in two ways:

- Difficult: dead-end branches going toward target
- Easy: dead-end branches away from the target



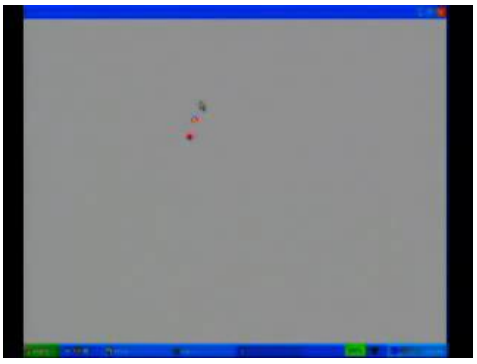
## Results

- Difficulty significantly affected response time and errors

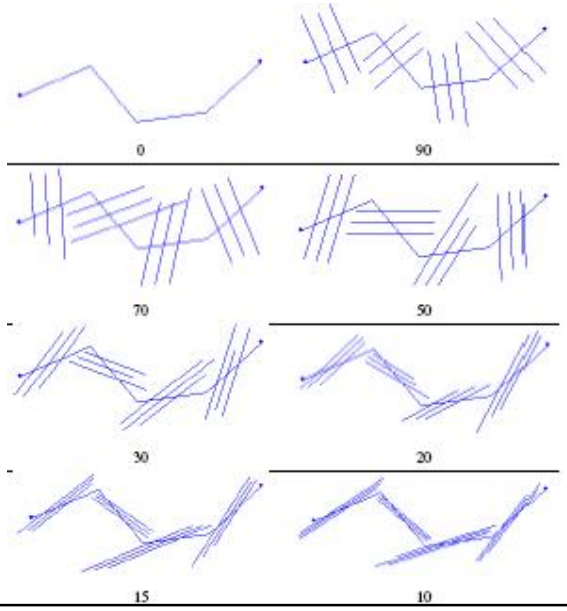



## Discussion and an Example of Video

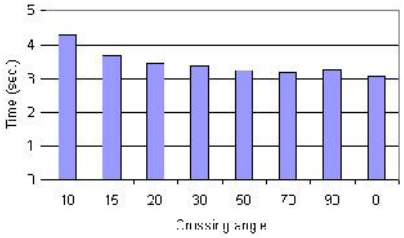
- Geodesic-path tendency affected performance of shortest path tasks significantly.

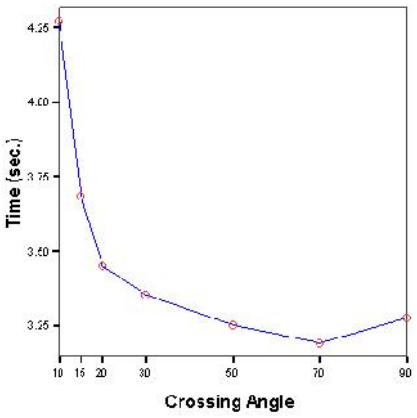


## Ex4: Effects of Crossing Angles




## Results



## Results

- Linear component and a quadratic component in the relationship between time and angle.
- $70^{+}$ degree angle was equivalent to that with no-crossings.

## Conclusion

- Eye movements tell us *how:*
  - How crossings affect eye movements and performance
  - Impact of crossings differs with crossing angle and size of graphs
  - People have geodesic-path tendency in searching shortest paths
- To obtain insights on *why*, post-task interviews can used.