Visual Thinking Algorithms

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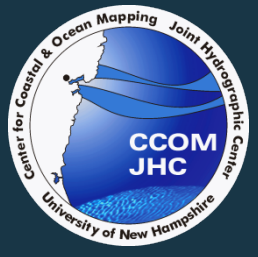
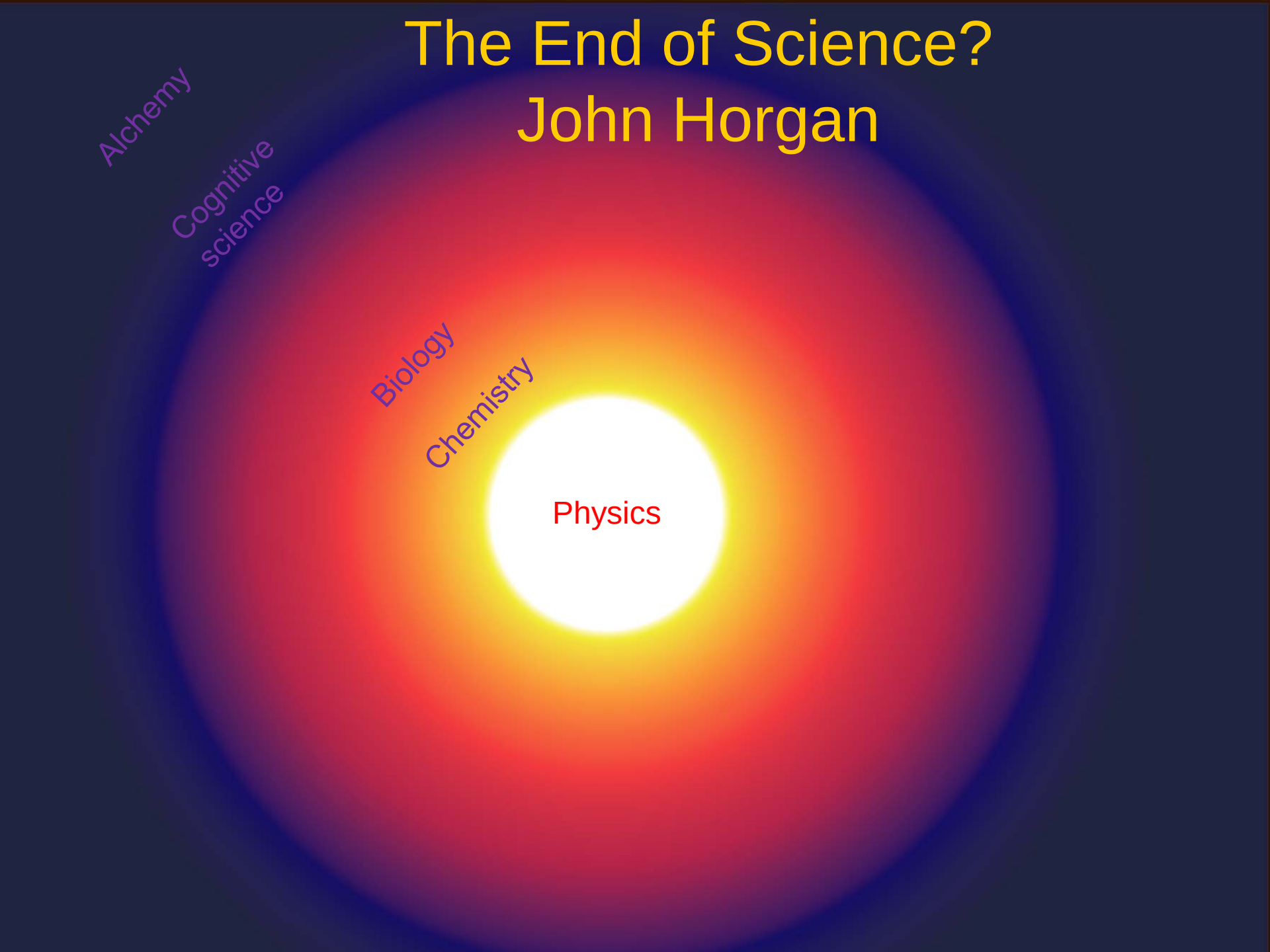
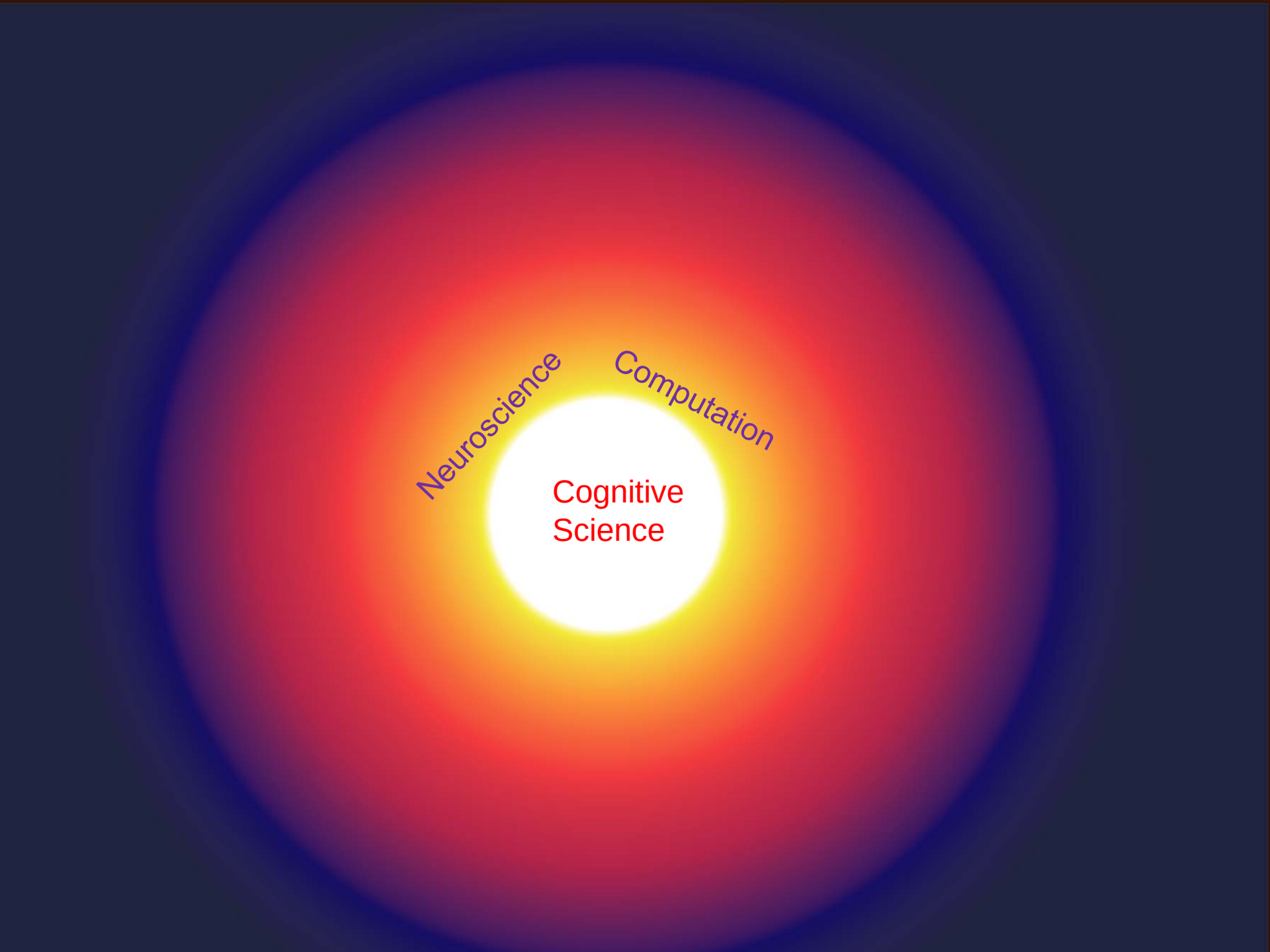
University of New Hampshire

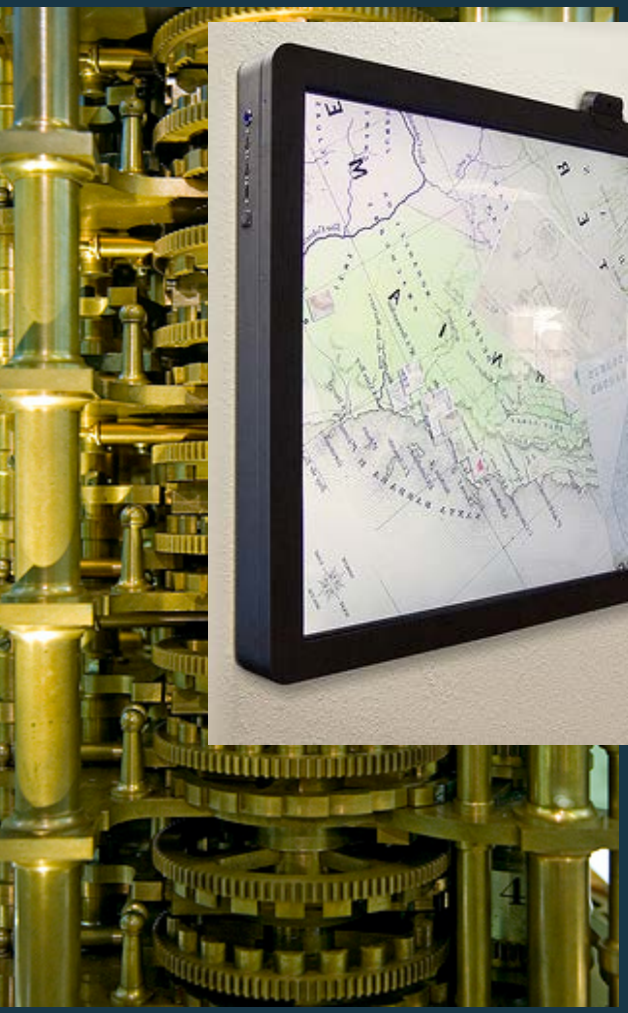


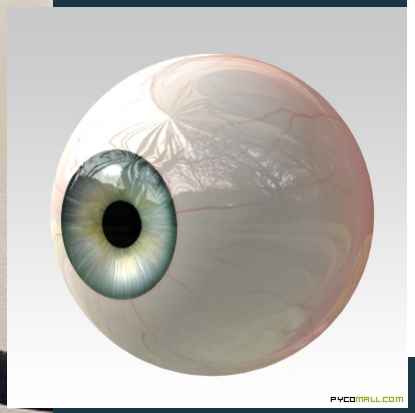
The End of Science?
John Horgan




Neuroscience
Computation
Cognitive
Science

The rise of the cognitive cyborgs

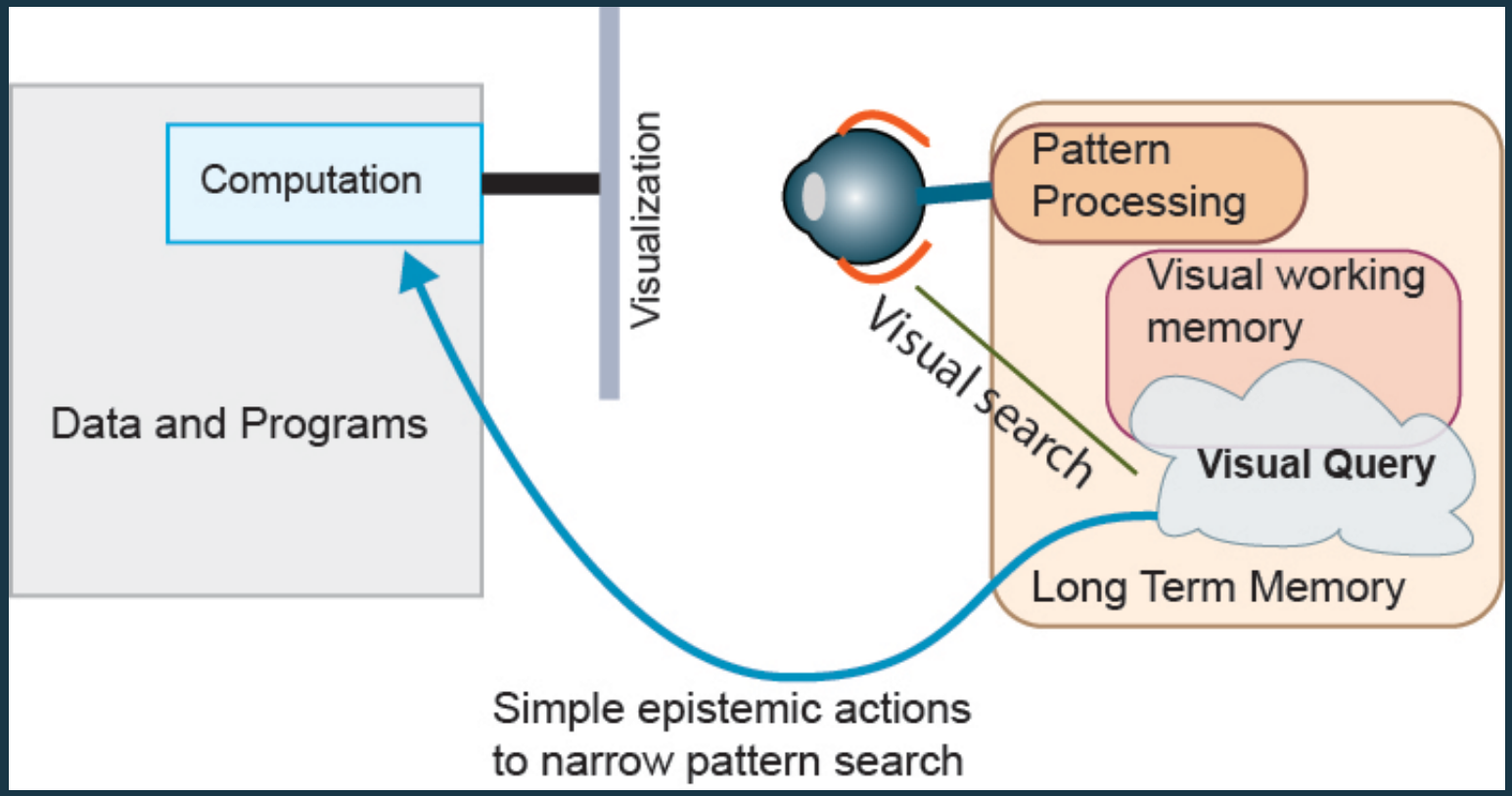




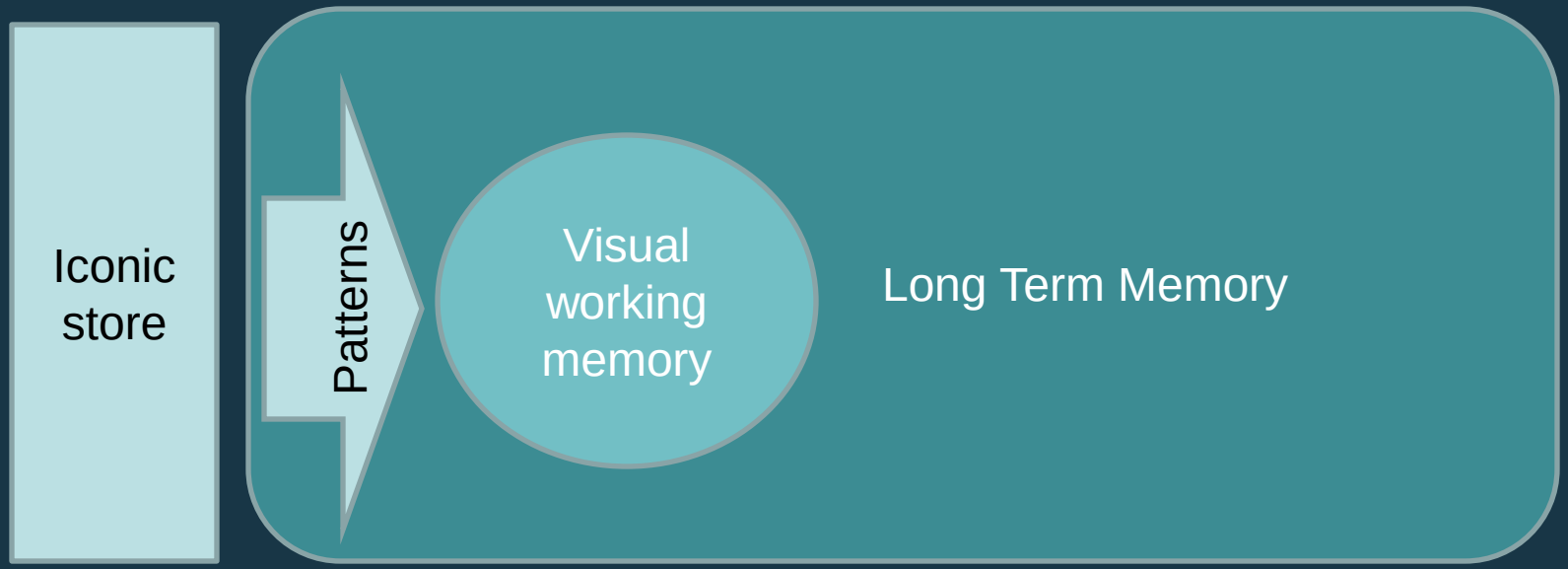
How does visual thinking work

- Visual working memory
- Pattern Perception
- Visual Queries
- Epistemic actions (Kieras)

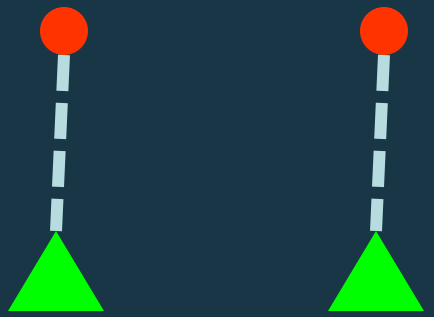
- Pseudo code to describe process

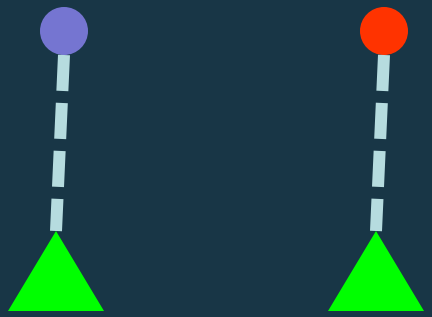

Computation
Data and Programs
Visualization
Pattern Processing
Visual working memory
Visual search
Visual Query
Long Term Memory
Simple epistemic actions
to narrow pattern search

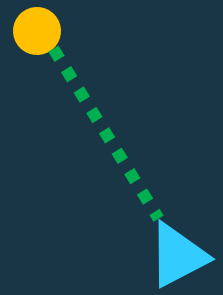
Visual memories

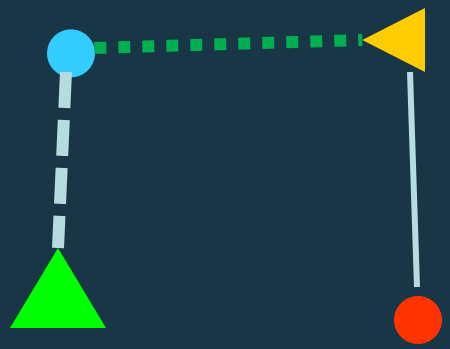


Visual working memory



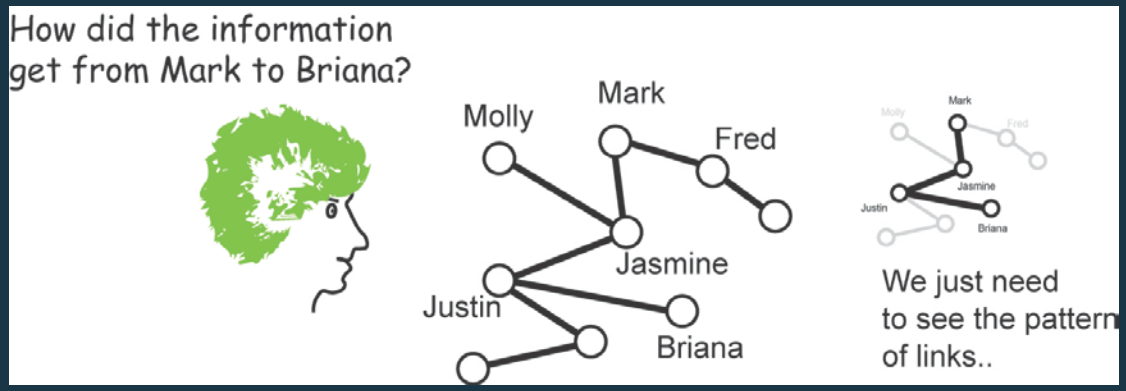




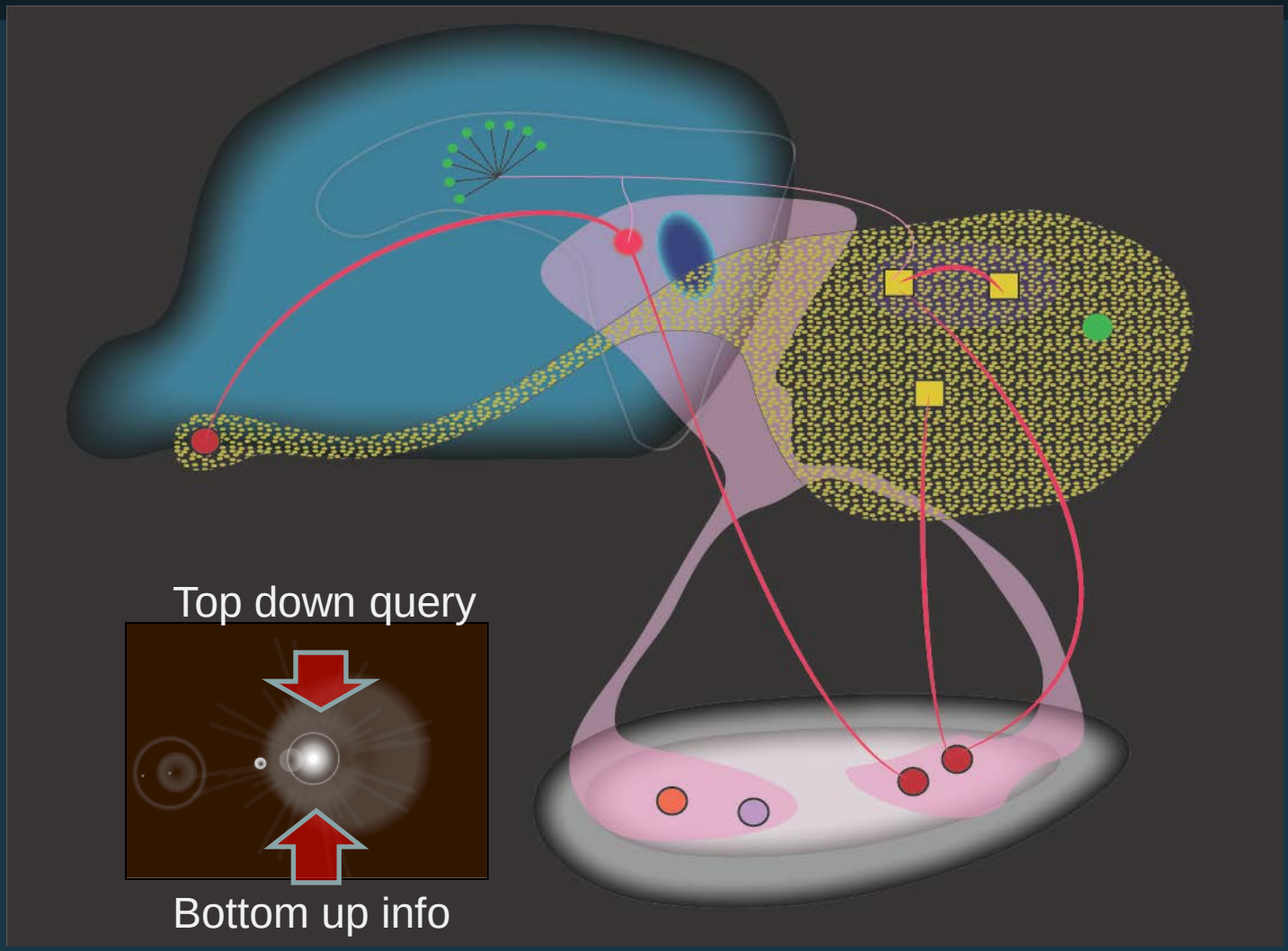


The visual query

- Transforming a problem into a pattern search
- E.g. path in a network diagram



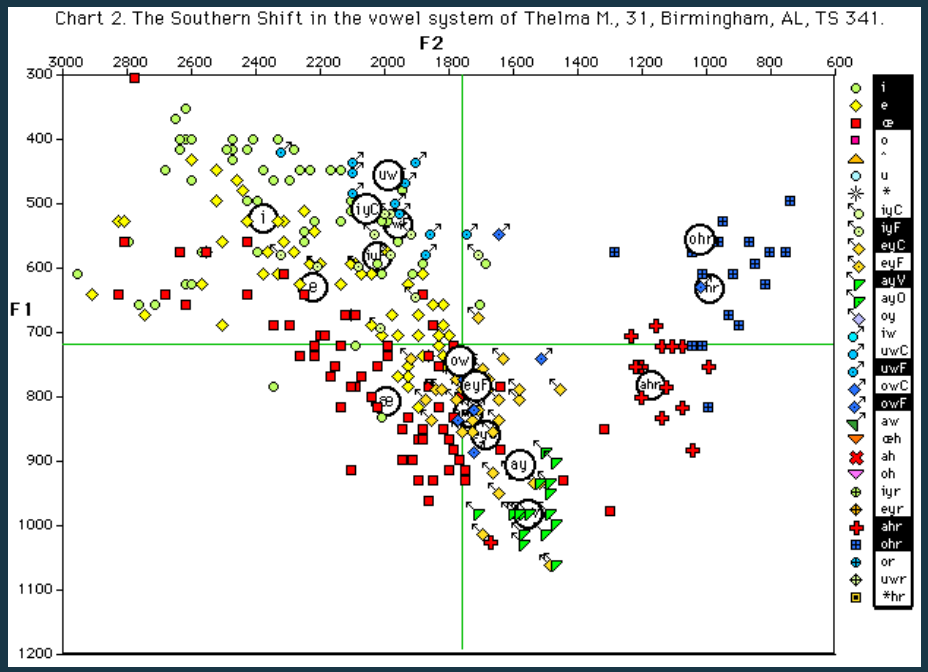
Visual Pattern Perception



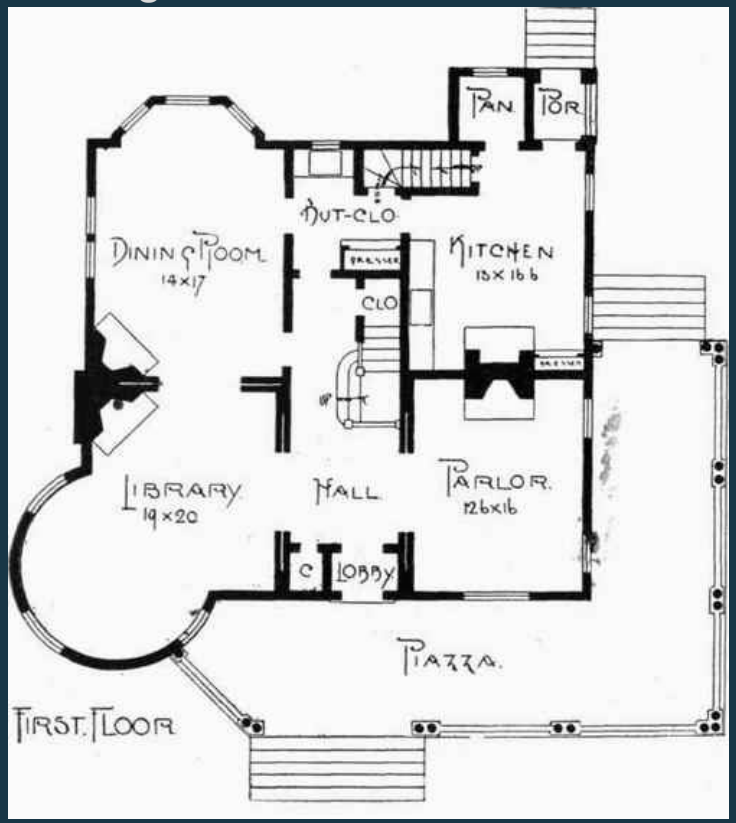
More visual queries

Vowel formants

Can I use a simple frequency analysis
To identify vowel sounds



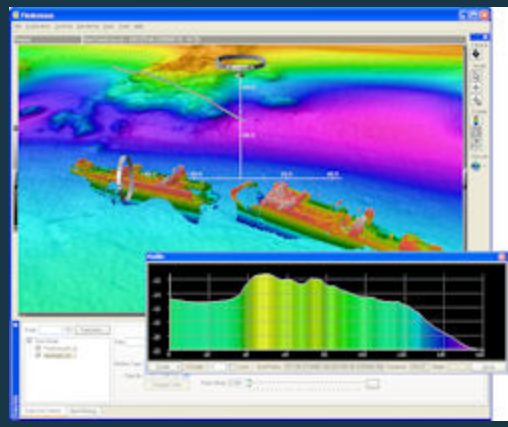
How far from the kitchen to the Dining room



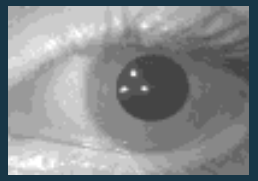
Epistemic actions

- Actions executed to seek knowledge
- E.g. an eye movement. 70 msec
- Or – brushing, dynamic queries, zooming

- The essence of interactive visualization



Epistemic actions



Externalization

- I take something I have learned and put it in the computer

Mental Imagery

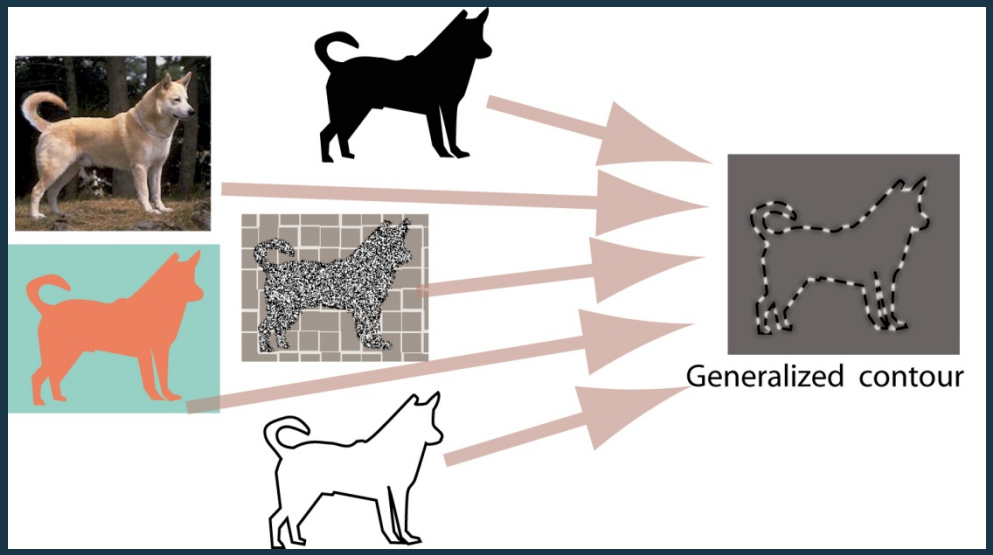
Combining mental imagery with external imagery

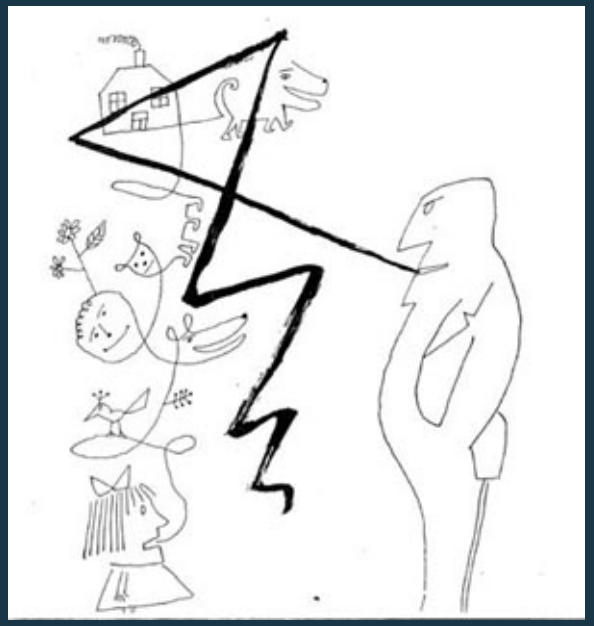
Shimojima (2008)

A>B
C>A

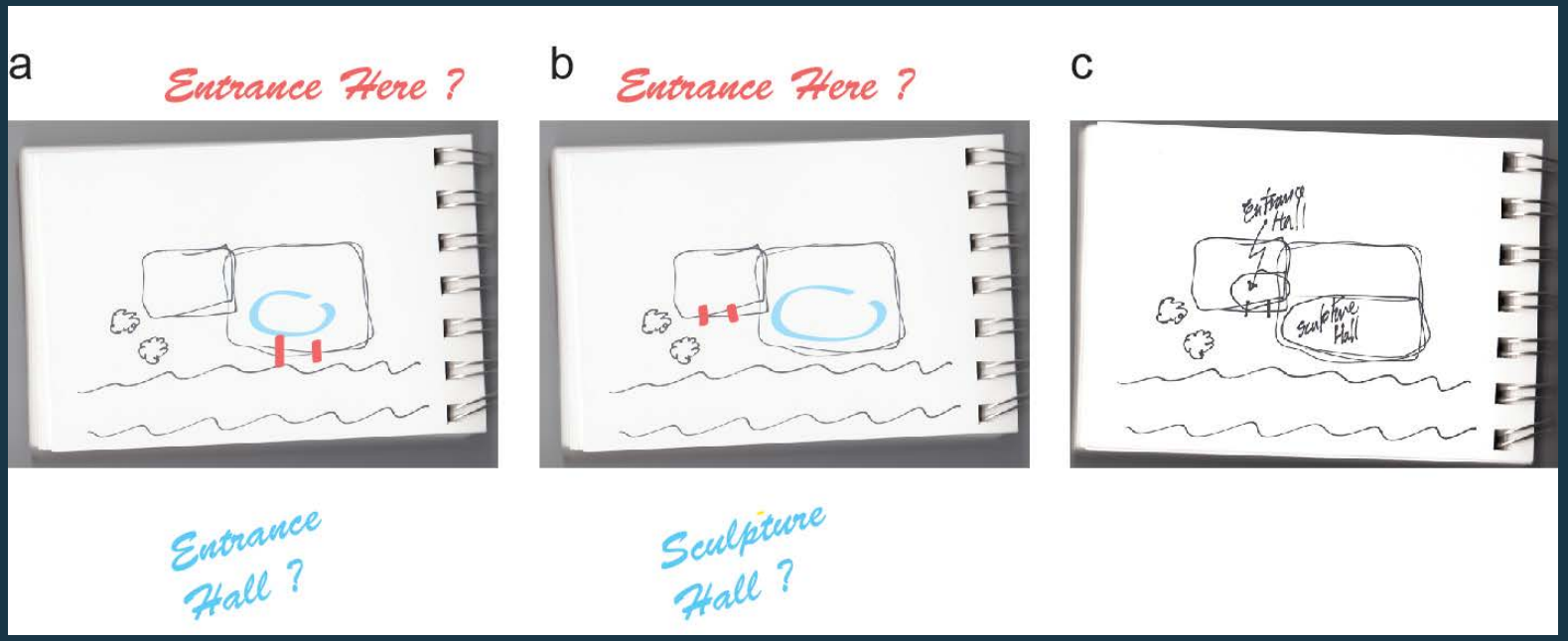
C>B?

The magic of lines





ALG 1: Design Sketching



ALG 1: Design Sketching

Design sketching

1. *Mentally image some aspect of a design.*
2. *Put marks on display to externalize aspects of the imagined design.*
3. *Construct analytic visual queries to determine if design meets task requirements.*

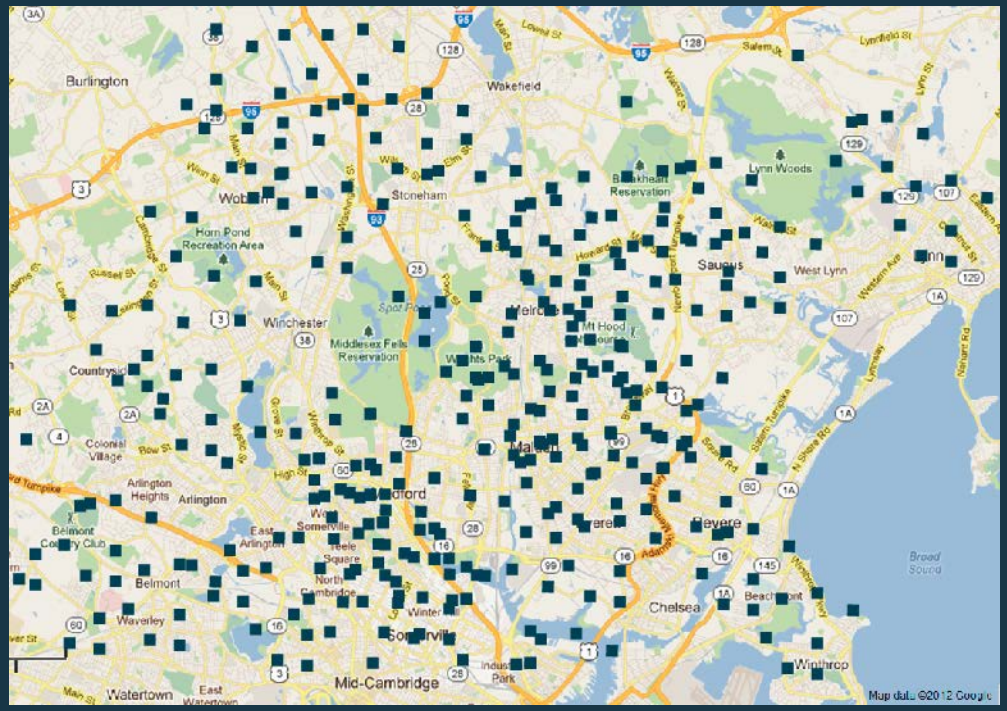
8. *Repeat from 1 revising sketch or discard sketch and begin again.*

- Sketches are useful because of the limits of visual imagery

ALG 2: Generalized Fisheye Views. Furnas (1986)

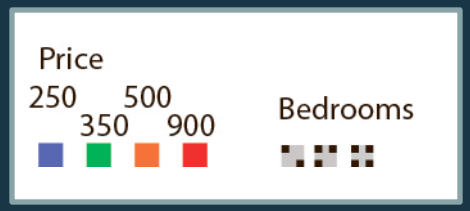
- I touch something.
- Computer shows related information according to a Degree of Interest function (DOI). It hides less relevant information

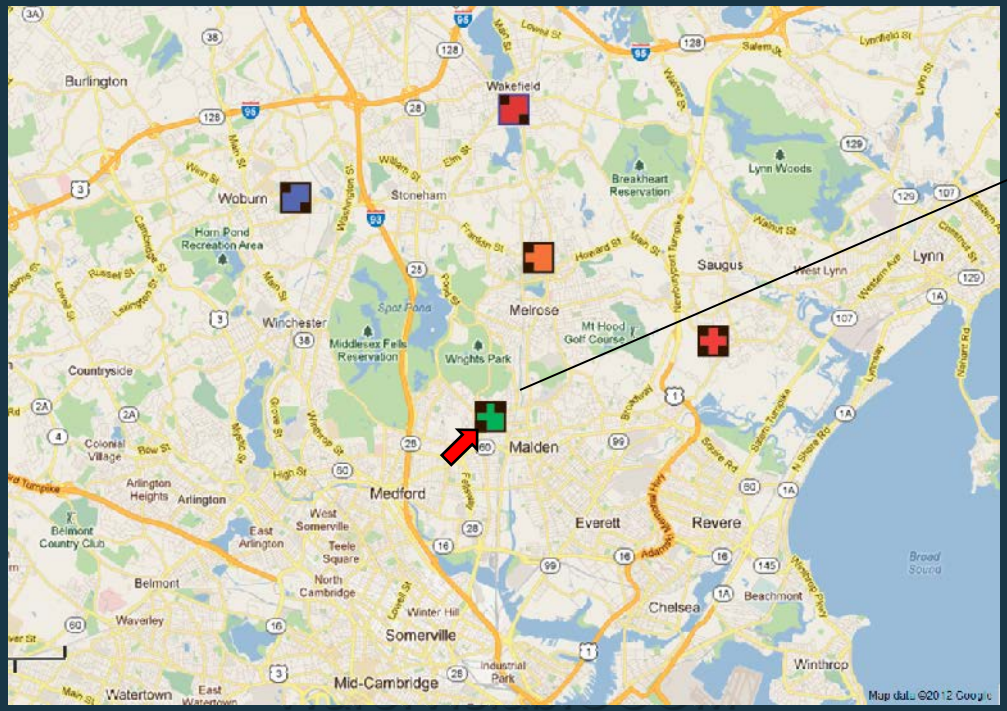
Real estate search

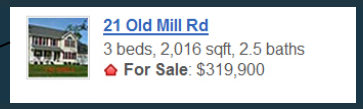


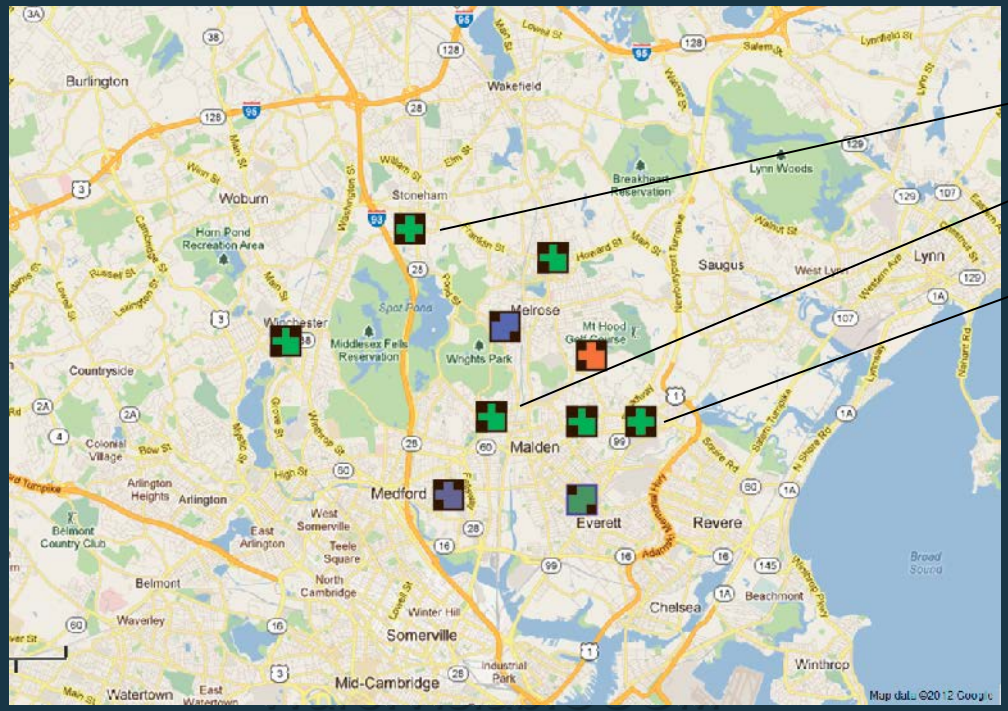
Need a visual clue

For generalized fisheye we need visual scent









44 Evans Rd
4 beds, 2,240 sqft, 2.5 baths
For Sale: $329,900

21 Old Mill Rd
3 beds, 2,016 sqft, 2.5 baths
For Sale: $319,900

145 Concord Rd
4 beds, 3,688 sqft, 3.0 baths
For Sale: $329,000

A2: Generalized fisheye views

1. *Construct and execute a visual query to find information that may be accessed via a particular symbol (information scent).*
2. *Execute an epistemic action by selecting a symbol, similar to target.*
3. *Computer displays all symbols representing data above computed relevance threshold. Symbols may be weighted by relevance so that most relevant are most salient and displayed with most detail.*
   - *3.1 Symbols with a low computed relevance are hidden.*
4. *If a very high relevance symbol is found execute an epistemic action to drill down for additional information. Usually this will be presented in a different display window.*
5. *Repeat from 1 as needed, mentally marking locations of visited symbols.*

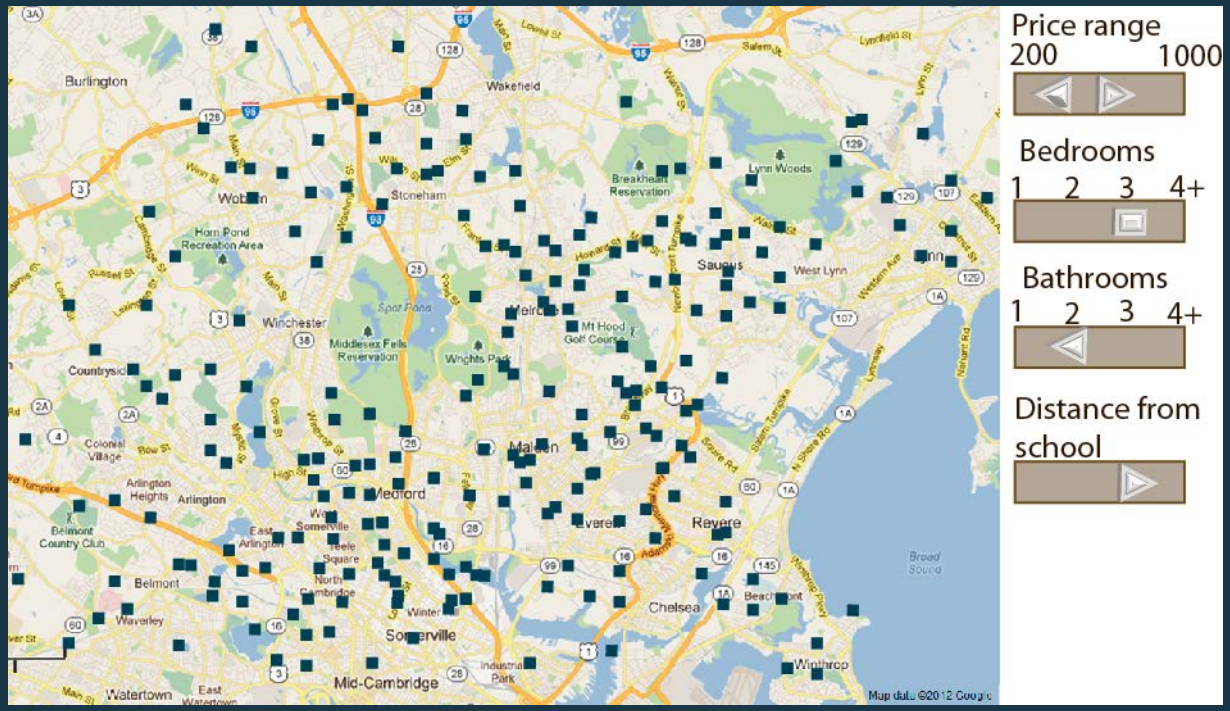
Analysis

- $Time = p_d \, x \, t_d \; + p_{nd} \, x \, t_{nd}$
- t_{nd} depends on the number of iterations
- Conclusion: Only useful if p_{nd} is small

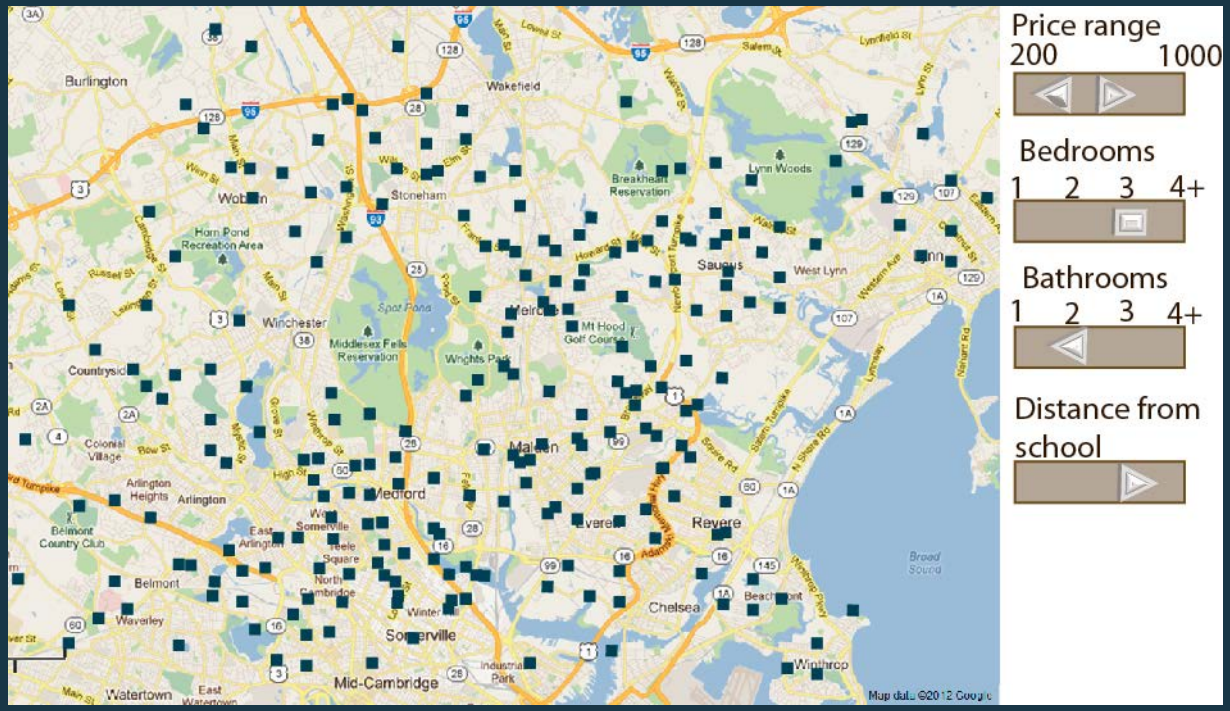
- Symbols must be informative

- Not useful for finding the set of suitable houses. Useful for detailed information

ALG 3: Dynamic query solution
(Williamson and Shneiderman, 1992)



Dynamic query solution



ALG 3: Multi-dimensional dynamic queries with scatter plot (Williamson and Shneiderman, 1992)

1. *User constructs task relevant visual pattern query.*
   2.1 *Is the number of targets small enough to make more detailed visual analysis feasible?*
   2.2 *Is the pattern found?*
3. *If high relevance symbol is found, execute an epistemic action to drill down for additional information.*
4. *Execute an epistemic action, dragging a slider which causes the computer to adjust a range on a data dimension and display the modified subset of the data.*
5. *Repeat until either task is successfully completed or abandoned.*

Analysis

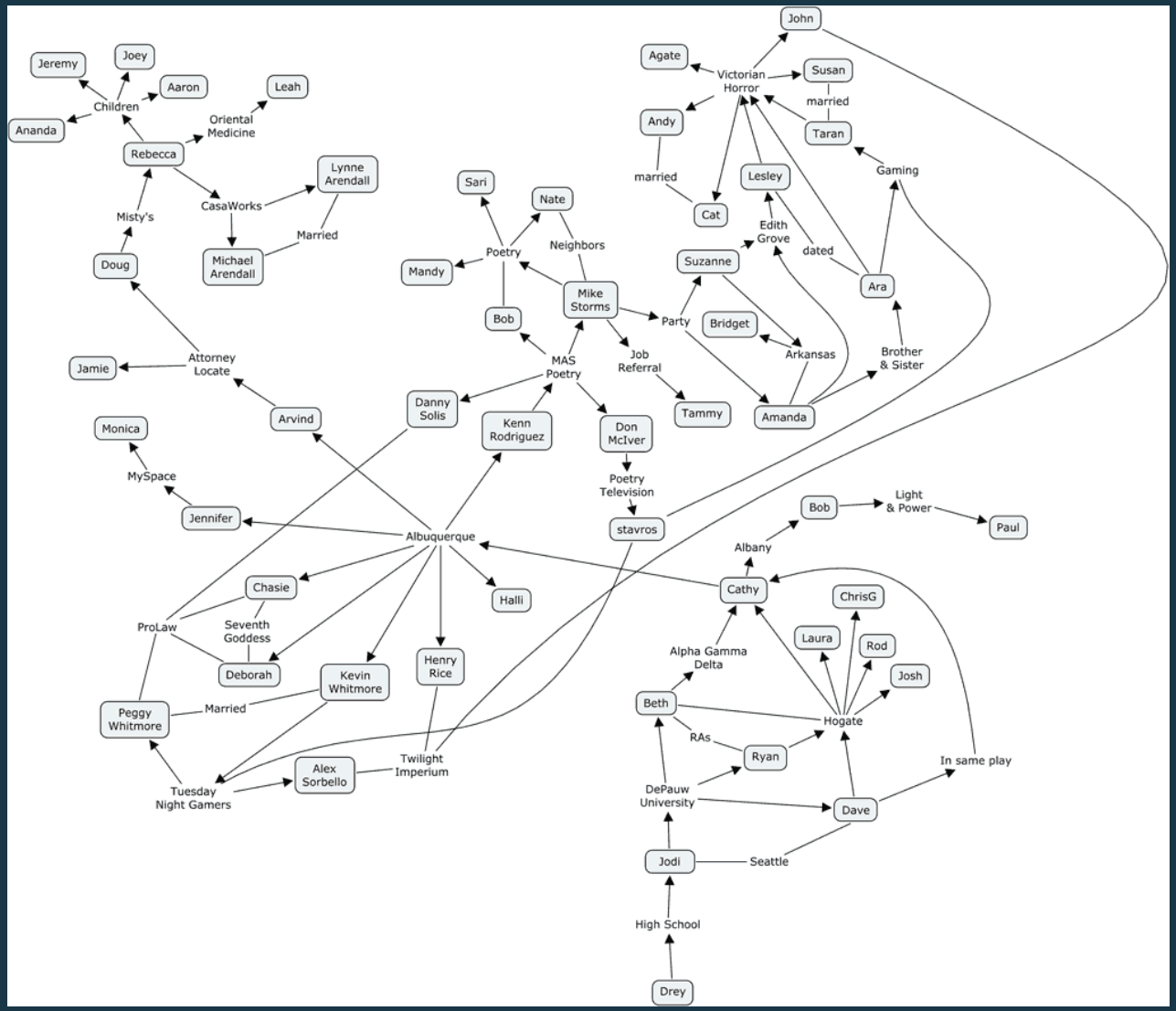
- Number on screen
- $n = N \prod r_i$
- Most useful if r_i are small
- E.g. 5 dimensions reduction to 10% on each. n = 0.00001 N

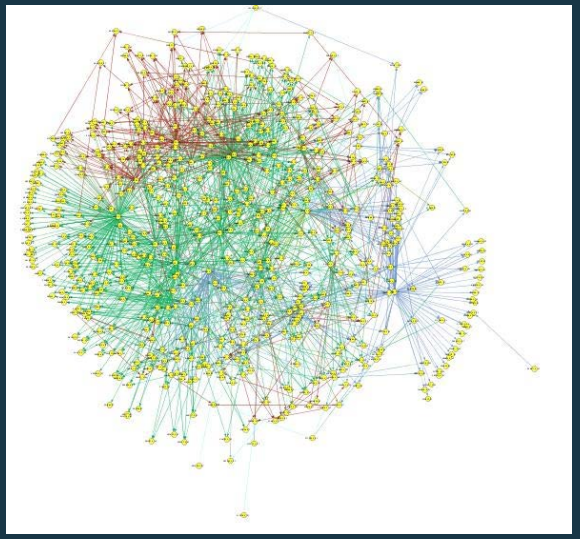
- But in real estate 3 bed 2 bath room houses are very common.

Best solution

- Use dynamic queries – for screening – or simply put in query values
- + Generalized fisheye for information not to narrow the field.
- Big win: Optimize response to epistemic actions– flash up pictures of houses + extra information using hover queries

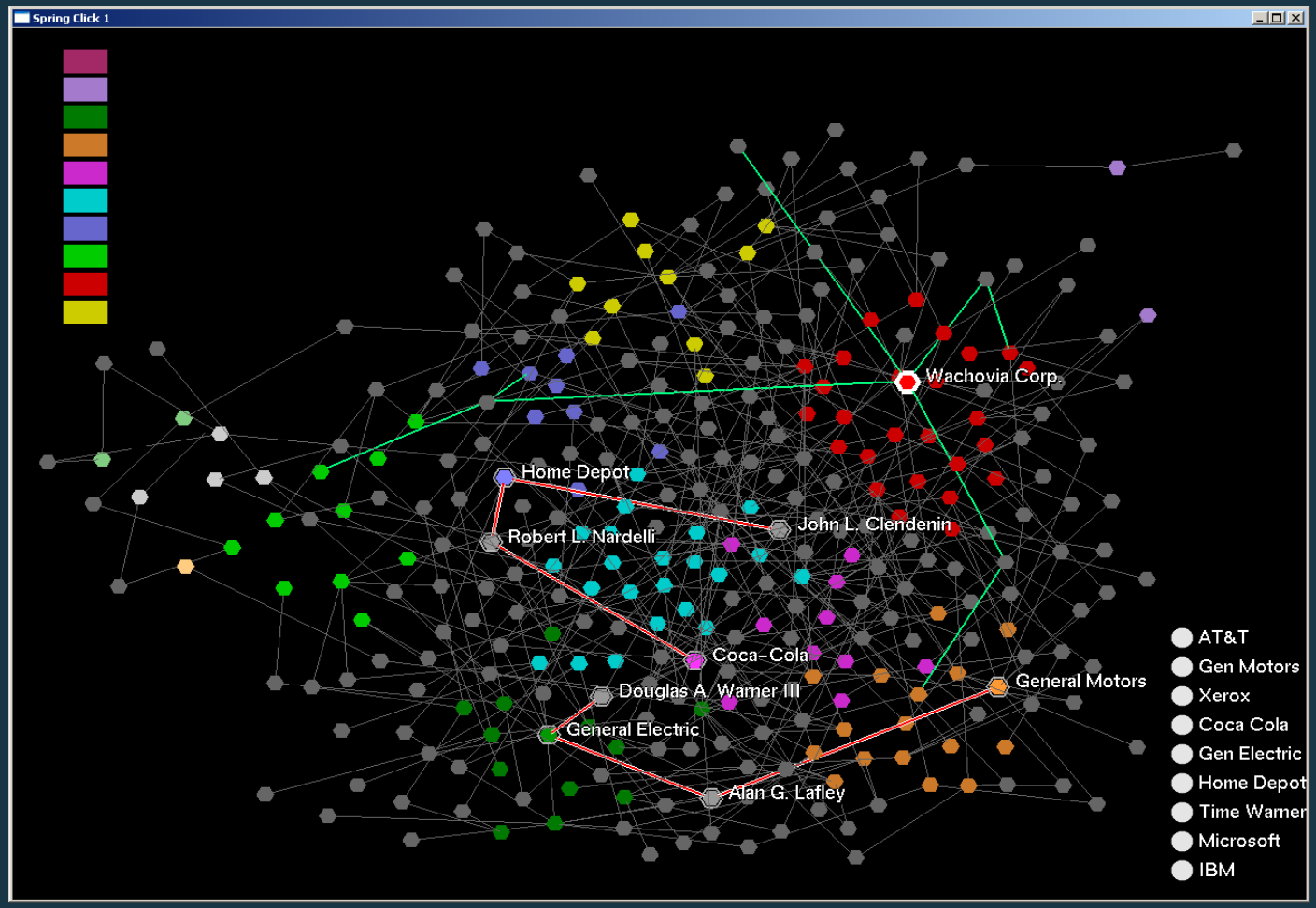
Network diagram





ME Graph

Original idea from Constellation (Munzner et al)



ALG 4:Degree of relevance highlighting

1. *Construct visual query to find a symbol that may lead to useful information (information scent).*
2. *Execute an epistemic action by selecting a symbol.*
3. *Computer highlights all symbols with a high degree of relevance to selected symbol.*
4. *Execute a visual pattern query among highlighted symbols.*
5. *If a very high relevance symbol is found, externalize.*
6. *Repeat from 1 as needed, cognitively marking visited*

Analysis

- Solves the problem for a network of < 500 items
- Epistemic action rate can be one per second

Why this level of description?

- This is how visual thinking happens
- Visual thinking algorithms can help with the cognitive process level
  - *How big a problem can be addressed*
  - *Visual search requirements*
  - *Visual working memory load issues*
- A tool for the system designer