Visual Thinking Algorithms

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Physics
Cognitive Science

Neuroscience
Computation
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
Data and Programs

Computation

Visualization

Simple epistemic actions to narrow pattern search

Pattern Processing

Visual working memory

Visual Query

Long Term Memory
Visual memories

Iconic store

Patterns

Visual working memory

Long Term Memory
Visual working memory
The visual query

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

Top down query

Bottom up info
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

Chart 2. The Southern Shift in the vowel system of Thelma M., 31, Birmingham, AL, TS 341.
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

a) Entrance Here?  
b) Entrance Here?  
c) Entrance Hall?  
Sculpture Hall?
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.

- 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
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

- \( Time = p_d \times t_d + p_{nd} \times t_{nd} \)
- \( t_{nd} \) 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