Perception 2

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Papers

- Perceptual enhancement: text or diagrams?
  - *Why a Diagram is (Sometimes) Worth Ten Thousand Words*

    Larkin, J. and Simon, H.A
- Structural object perception: 2D or 3D?
  - *Diagrams based on structural object perception*

    Ware, C. and Irani, P.
- Preattentive processing: texture and color?
  - *Large Datasets at a Glance: Combining Textures and Colors in Scientific Visualization*

    Healey, C. and Enns, J.

"Why a Diagram is (Sometimes) Worth Ten Thousand Words"

Jill H. Larkin, Herbert A. Simon.
Cognitive Science, Vol. 11, No. 1, pp. 65-99, 1987.

2 different representations

Which is better?

- Sentential
  - Sequential, like propositions in a text,
- Diagrammatic
  - Indexed by location in a plane

Better representation?

"Better"

- Informational equivalence
  - All information in one is also inferable from the other, and vice versa
- Computational equivalence
  - informationally equivalent plus any inference in one is just as easy and fast as the same inference in the other.

Better representation?

"Representation"

- Data Structures
  - Single sequence or indexed 2-dimentional
- Attention Management
  - Determines what portion of the data structure is currently attended to
- Programs
  - Processes: Search, recognition, inference

Processes

- Search
  - Operates on the data, seeking to locate sets of elements that satisfy the conditions of one or more productions
- Recognition
  - Matches the condition of elements of a production to data elements located through search
- Inference
  - Executes the associated action to add new elements in the data structure

Note

- Human recognition is dependent on particular representations which match processes that the person is already familiar with.

Example 1

- Pulley Problem

Natural Language statement

We have 3 pulleys, two weights, and some ropes, arranged as follows:

1. 1st weight is suspended from the left end of a rope over pulley A. The right end of this rope is attached to, and partially supports, the second weight
2. Pulley A is suspended from the left end of the rope that runs over pulley B, and under Pulley C. Pulley B is suspended from the ceiling. The right end of the rope that runs over pulley C is attached to the ceiling.
3. Pulley C is attached to the second weight, supporting it jointly with the right end of the first rope.

The pulleys and ropes are weightless; the pulleys are frictionless; and the rope segments are all vertical, except where they run over or under the pulley wheels. Find the ratio of the second to the first weight, if the system is in equilibrium.

Example 1 - Sentential

Data Structure

```
           (Weight W1) (Rope Rp) (Rope Rq) (Pulley Pa)
(1a.1)     (hangs W1 from Rp)
(1a.2)     (pulley-system Rp Pa Rq)

           (Weight W2)
(1b.1)     (hangs W2 from Rq)

           (Rope Rx) (Pulley Pb) (Rope Ry) (Pulley Pc) (Rope Rz)
           (Rope Rt) (Rope Rs) (Ceiling c)
(2a.1)     (hangs Pa from Rx)
(2a.2)     (pulley-system Rx Pb Ry)
(2a.3)     (pulley-system Ry Pc Rz)
(2b.1)     (hangs Pb from Rt)
(2b.2)     (hangs Rt from c)

(3a.1)     (hangs Rx from c)
(3a.2)     (hangs Rs from Pc)
(3b.3)     (hangs W2 from Rs)

(4.1)      (value W1 1)
```

Example 1 - Sentential

Program: Inference Rules

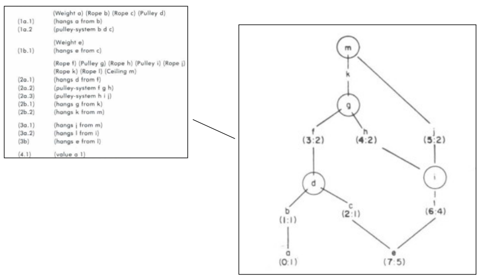
```
P1. Single-string support. (weight <Wx>) (rope <Ry>)
    (value <Wx> <n>) (hangs <Wx> <Ry>)
    ~(hangs <Wx> <Rx>)
    → (value <Ry> <W-number>)
P2. Ropes over pulley. (pulley <P>) (rope <R1>) (rope <R2>)
    (pulley-system <R1> <P> <R2>) (value <R1> <n1>)
    → (value <R2> <n1>)
P3. Rope hangs from or supports pulley. (pulley <R1>) (rope <R1>) (rope R2>)
    (pulley-system <R1> <P> <R2>) { (hangs <R3> from <P>) or (hangs <P>
    from <R3>) } (value <R1> <n1>) (value <R2> <n2>)
    → (value <R3> <n1 + <n2>)
P4. Weight and multiple supporting ropes. (weight <W1>) (rope <R1>) (rope
    R2>) (hangs <W1> <R1>) (hangs <W1> <R2>) ~(hangs <W1> <R3>)
    (value <R1> <n1>) (value <R2> <n2>)
    → (value <W1> <n1> + <n2>)
```

Example 1 – Sentential

Inference Rules "Translated"

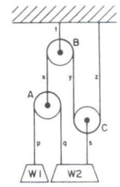
1. Because weight *W1* (value 1) hangs from rope *Rp* and no other rope, the value associated with *Rp* is 1
2. Because *Rp* and *Rq* pass over the same pulley, the value of *Rq* is 1
3. Because *Rp* (value 1) and *Rq* pass over the same pulley, the value *Rq* is 1
4. Because *Rx* (value 2) and *Ry* pass over the same pulley, the value of *Ry* is 2
5. Because *Ry* (value 2) and *Rz* pass under the same pulley, the value of *Rz* is 2
6. Because *Ry* and *Rz* have values 2, and the pulley *Pc* which they pass is supported by *Rs*, the value associated with *Rs* is 2+2=4.
7. Because weight *W2* is supported by rope Rq (value 1) and rope *Rs* (value 4) and no other ropes, its value is 1 + 4 =5

Example 1 – Diagrammatic



Example 1

- Physics Pulley Problem
- Diagrammatic representation required less search



Example 2

- Geometry problem
- Significant problems in sentential representation:
  - Search for matching conditions
  - Recognition for conditions of inference rule
    - The original given statement does not include elements that can be recognized by the inference rules in the given problem

Example 2

- Advantages in diagrammatic:
  - Perceptual enhancement of the data structure
  - Computational difference in recognition
  - Considerable search differences

Benefits of diagrammatic over sentential

- Can group together all information that is used together
- Use location to group information about a single element
- Automatically support a large number of perceptual inferences
- Perceptually enhanced data structures are easier to comprehend.

Conclusion

- diagrammatic representations:
  - reduce search
  - primary difference: dramatically reduce the recognition process.
  - once the search and recognition processes have taken place, the process of inferencing requires approximately the same level of resources.

Evaluation

- Strengths
  - Convincing
  - No ambiguity in what authors are trying to prove
  - Sets criteria for evaluating representations through tasks
- Weaknesses
  - Barely a mention of the “User Study”
  - Examples are very detailed, an overview would have been fine

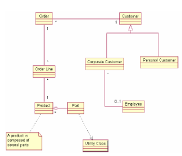
Diagramming information structures using 3D perceptual primitives

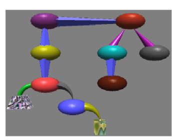
Pourang Irani and Colin Ware.

ACM Transactions on Computer Human-Interaction. 10(1): 1-19 (2003)

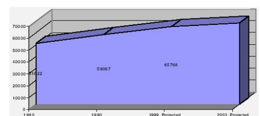
3D primitives

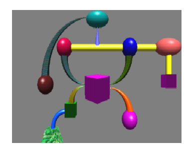
- Will drawing three-dimensional shaded elements instead of using simple lines and outlines result in diagrams that are easier to interpret?

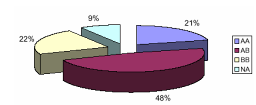


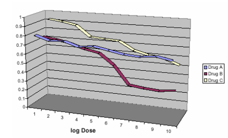


Another gratuitous 3D graphic?









Theories of object perception

- Image-based theories:
  - Emphasizes the properties of visual images
  - Suggests that we recognize objects based on the similarities of the image they present with the images of previously viewed objects
- Structure-based theories
  - Emphasizes viewpoint independent analysis of object structure

Image-based theories

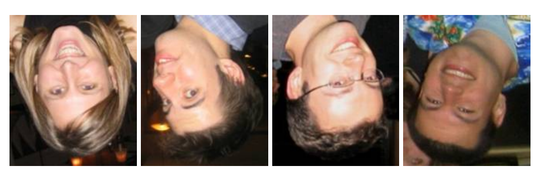
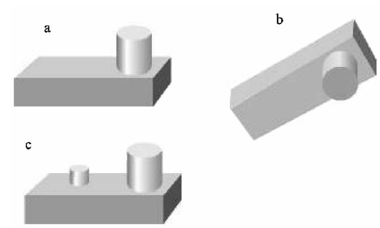
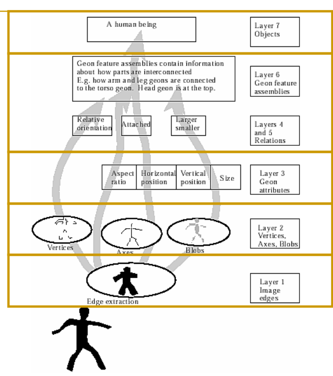


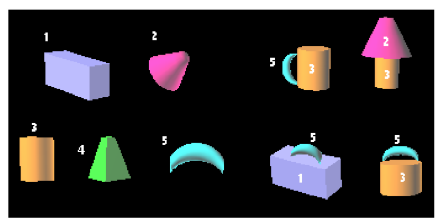
Image-based theories

Structure-based Theories





Geons



Applying theory to diagrams

Rules of the Geon Diagram

G1: Major entities of a system should be presented using simple 3D shape primitives (geons).
G2: The links between entities can be represented by the connections between geons. Thus the geon structural skeleton represents the data structure.
G3: Minor subcomponents are represented as geon appendices, small geon components attached to larger geons. Mapping object importance to object size seems intuitive.
G4: Geons should be shaded to make their 3D shape clearly visible.
G5: Secondary attributes of entities and relationships are represented by geon color and texture and by symbols mapped onto the surfaces of geons.

Applying theory to diagrams

Layout Rules

L1: All geons should be visible from the chosen viewpoint.
L2: Junctions between geons should be made clearly visible.
L3: The geon diagram should be laid out predominantly in the plane orthogonal to the view direction.

Geon toolkit developed to draw geons

Experiments

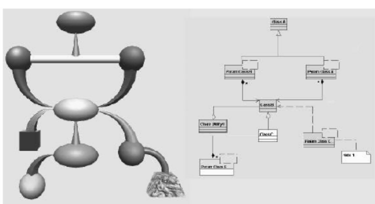
- 5 experiments
  - Note: to see if it is better than node-link diagrams in general, not UML
- 3 experiments: geons vs UML
- 2 experiments: geons vs 2D version
- Testing Search and Recognition

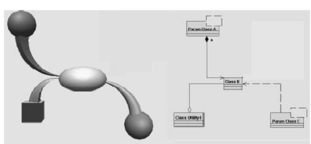
Experiment 1

- Substructure identification
- Method
  - Subjects were first shown a substructure and later asked to identify its presence or absence in a series of diagrams
- Results

	Geon	UML
Identification time (sec)	4.3	7.1
Error rate	13.33%	26.33%

- Conclusion
  - Geon diagrams are easier and faster to interpret than UML diagrams





Experiment 2

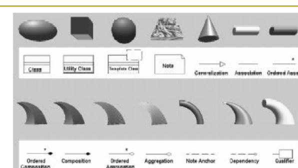
- Recall of Geon versus UML diagrams
- Method
  - 2 sets of students in Sr level CS
  - Set of diagrams shown at the beginning of lecture, then full set presented 50 minutes later.
- Results

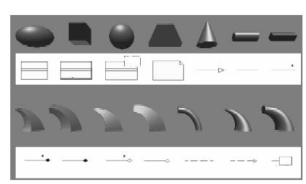
  Geon diagrams 18% error rate vs UML 39%
  35 subjects:
  26 recalled correctly more Geon than UML
  5 recalled correctly same number
  4 recalled correctly more UML
- Conclusion
  - Geon diagrams are easier to remember

Experiment 3

- Recall of Geon versus UML diagrams without surface attributes
- Method
  - Same as Experiment 2
- Results

  Geon diagrams 22.5% error rate vs UML 42%
  35 subjects:
  25 recalled correctly more Geon than UML2
  recalled correctly same number
  8 recalled correctly more UML
- Conclusion
  - Strongly supports the hypothesis that remembering geon diagrams is easier than remembering UML diagrams even when not presented with surface attributes





Geons vs UML

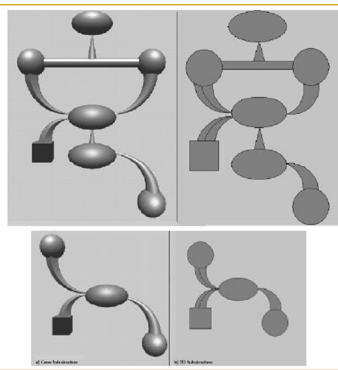
- Supports idea that geons are easier to interpret and remember than UML, but this cannot be generalized
- Too many differences between goens and UML to conclude that results are due to 3D primitives
- Test with a direct translation to 2D

Experiment 4

- Substructure identification with Geon vs 2D sillhouette diagrams
- Method
  - Identical to Experiment 1
- Results

	Geon	2D Silh
Identification time (sec)	4.1	5.3
Error rate	12.11%	19.24%

- Conclusion
  - Geon diagrams are easier and faster to interpret than 2D silhouette diagrams



Experiment 5

- Recall of Geon vs 2D Silhouette
- Method
  - Identical to Experiments 2 and 3
- Results

Geon diagrams 21.7% error rate vs 2D 31.2%
34 subjects:
25 recalled correctly more Geon than 2D
4 recalled correctly same number
5 recalled correctly more 2D

- Conclusion
  - Remembering geon diagrams is easier than their equivalent 2D silhouette diagrams

Problems

- May not be as compact
  - Not as good if information structure is large
- Text on a 3D area?

→ May be optimal for search (exp 1 and 4)
→ What about recognition (exp 2, 3 and 5), if important text that cannot be represented by surface attributes?

Evaluation

- Strengths
  - Addressed issues from previous paper (2001)
  - Well-done user experiments
  - Doesn't claim to be implying a new UML, but a general idea of node-link diagrams
- Weaknesses
  - Description of geon theory
    - Diagram in 2001 paper was removed
  - B&W diagrams

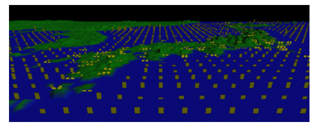
Large Datasets at a Glance: Combining Textures and Colors in Scientific Visualization

Christopher G. Healey and James T. Enns.
IEEE Transactions on Visualization and Computer Graphics 5, 2, (1999), 145-167

Problem

- How to visualize multivariate data elements arrayed across an underlying height field?

  → Simultaneous use of perceptual textures and colors



Related work

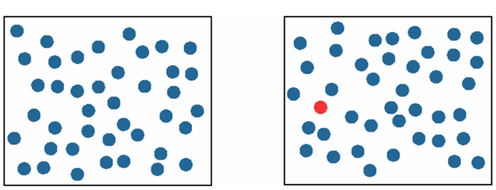
- Texture and color
  - Extensively studied in isolation
- Much less work focused on combined use of texture and color
  - Will color variation interfere with texture identification during visualization?

Key ideas:

- Preattentive Processing
- Visual Interference
- Best (re)introduced with an example
  - Target search

Test 1

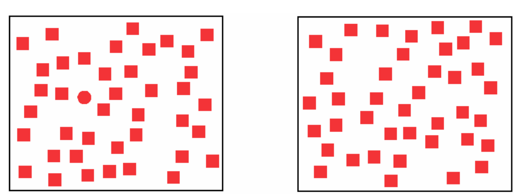
Find the red circle



A B

Test 2

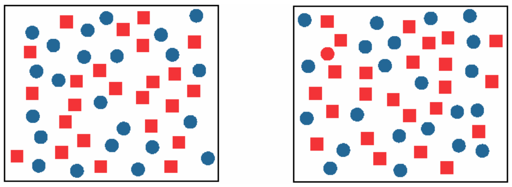
Find the red circle



A B

Test 3

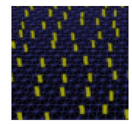
Find the red circle



A B

Multicolored Pexels

- **Pe**rceptual t**ex**ture **el**ements
- Represents each data element
- Attribute values encoded in an element are used to vary its appearance
- Glyph-like



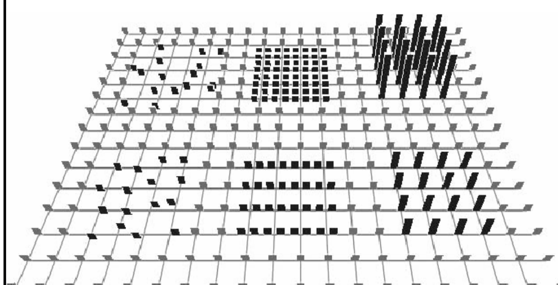
Texture

- Regularity
- Density
- Height

Regularity, Density: Primary texture dimensions

Height: Size: important property of texture dimension

Texture



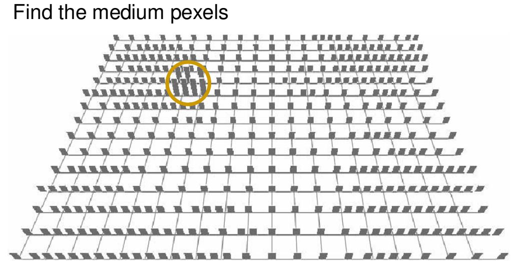
Regularity Density Height

Texture Experiments

1. Can the perceptual dimensions of density, regularity, and height be used to show structure in a dataset through the variation of a corresponding texture pattern?
2. How can we use the dataset's attributes to control the values of each perceptual dimension?
3. How much visual interference occurs between each of the perceptual dimensions when they are displayed simultaneously?

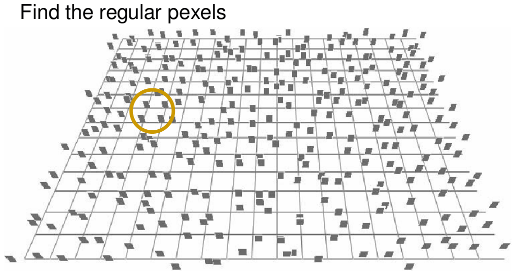
Example 1: Height

Find the medium pexels

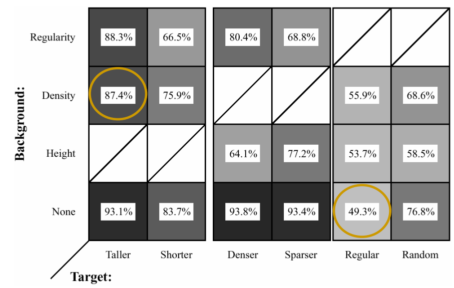


Example 2: Regularity

Find the regular pexels



Result Summary

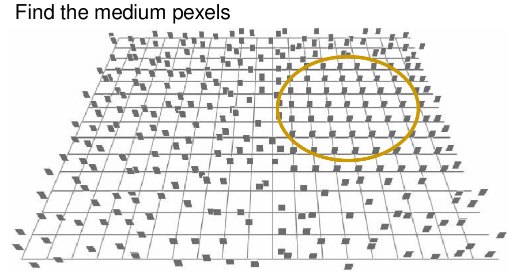


Regularity: further investigation

- Improve salience of patches
  - increase its size
  - Increase its minimum pexel density to be very dense

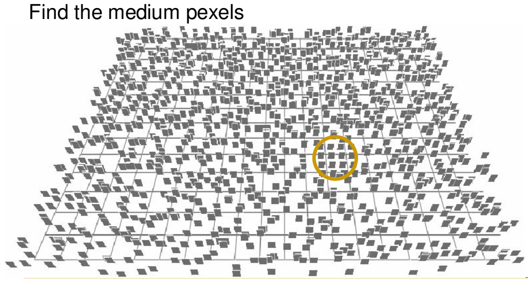
Regularity: further investigation

Find the medium pexels



Regularity: further investigation

Find the medium pexels



Conclusion: Texture

- Choose to display an attribute with low importance using regularity
  - Not preattentive
  - Used in focused or attentive analysis

Color Experiments

Select a set of *n* colors such that:

1. Any color can be detected preattentively, even in the presence of all other colors
2. The colors are equally distinguishable from one another

Color

- Color distance
- Linear separation
- Color category

Proper use of these criteria guarantees colors that are equally distinguishable from one another

Conclusion: Color

- Up to seven selected colors can be displayed simultaneously while still allowing for rapid and accurate identification
  - Only if the colors satisfy proper color distance, linear separation, and color category guidelines

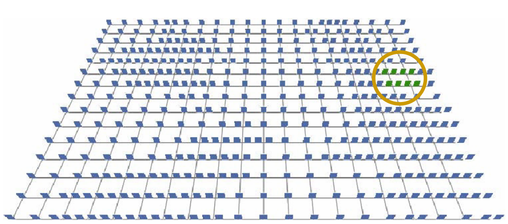
Combined texture and color

- Texture
- Color

Interference?

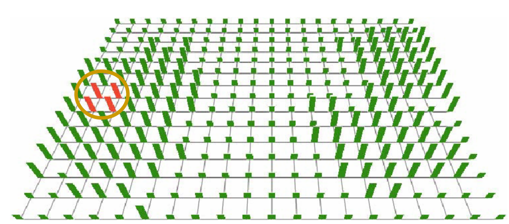
Example 1: Color

Find the green pexels



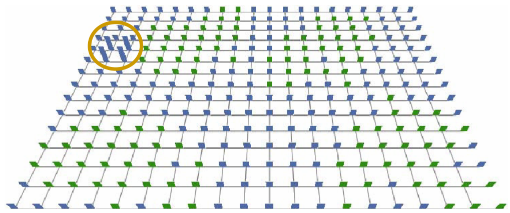
Example 2: Color

Find the red pexels



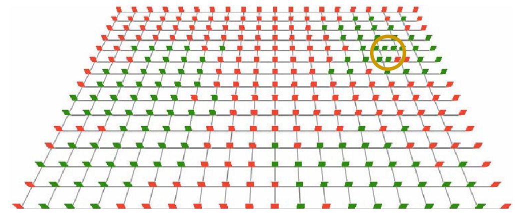
Example 3: Height

Find the tall pexels

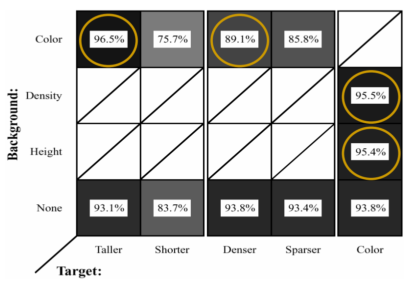


Example 4: density

Find the dense set of pexels



Result Summary



Conclusion: texture and color

- Background color variation
  - Small interference effect
  - But statistically reliable affect
  - Size of effect directly related to the difficulty of the visual analysis task
- Variation of height and density
  - No affect on identifying color targets

→ Solid design foundation

Real-world application

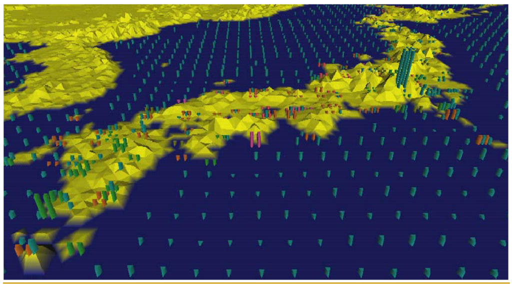
- Visualizing typhoons:
  - increased Wind speed — increased height
  - increased Pressure — decreased density
  - Increased Precipitation — color:

Purple
Red
Orange
Yellow
Green
No precipitation reported — Blue green

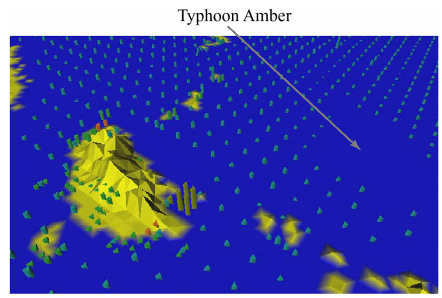
Real-world application

- No need to remember the exact legend
  - Designed to allow viewers to rapidly and accurately identify and track the locations of storms and typhoons
  - spatial collections of tall, dense, red and purple pexels

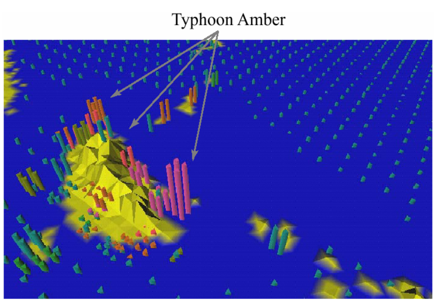
Visualizing Typhoons



Visualizing Typhoons



Visualizing Typhoons

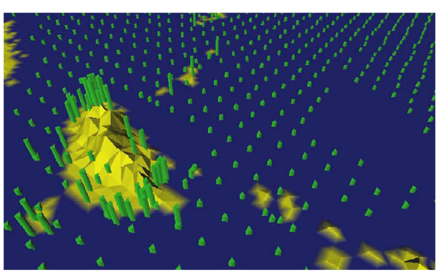


Real-world application

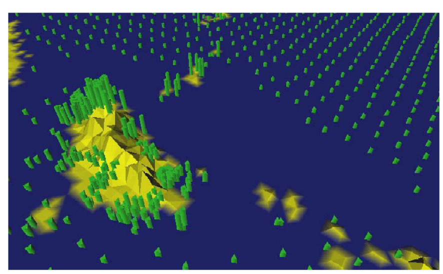
- Visualizing typhoons:
  - increased Wind speed — increased ~~height~~ regularity
  - increased Pressure — decreased ~~density~~ height
  - Increased Precipitation — ~~color:~~ density

Purple
Red
Orange
Yellow
Green
Blue green

Visualizing Typhoons



Visualizing Typhoons



Evaluation

- Strengths
  - Detailed user study
  - Application to real-world data
  - Provides plenty of background work
- Weaknesses
  - Length of paper
  - Just briefly mentions some observations user study done on the visualization of real data
  - Still limited to only 3 (maybe 4) attributes to display

References

Reviewed Papers:

- J. H. Larkin and H. A. Simon. Why a diagram is (sometimes) *worth ten thousand words*. Cognitive Science, 11(1):65--99, 1987.
- Pourang Irani and Colin Ware. Diagramming information structures using 3D perceptual primitives. ACM Trans. Comput.-Hum. Interact. 10(1): 1-19 (2003)
- Christopher Healey and James Enns. *Large datasets at a glance: Combining textures and colors in scientific visualization.* IEEE Transactions on Visualization and Computer Graphics, 5(2):145--167, April 1999. 2

Additional Sources:

- Pourang Irani and Colin Ware. *Diagrams Based on Structural Object Perception*, Conference on Advanced Visual Interfaces, Palermo, Italy. Proceedings: 61-67. (2000)
- Colin Ware. *Information Visualization: Perception for Design*. Morgan Kaufmann Publishers (2000). 274
- City of Cerritos - Housing Market Analysis, by R/Sebastian & Associates. http://www.ryansebastian.com/assets/pdf/report_market_analysis.pdf
- Displaying data badly: Using Microsoft Excel to obscure your results and annoy your readers http://www.biostat.jhsph.edu/~kbroman/teaching/labstat/third/notes02.pdf

Questions?