Representing Data with Patterns

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IAT 814 week 6
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Introduction

- Finding patterns is key to information visualization.
-
- Expert knowledge is about understanding patterns (Flynn effect)

- Example Queries: We think by making pattern queries on the world
  - Patterns showing groups?
  - Patterns showing structure?
  - When are patterns similar?
  - How should we organize information on the screen?

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Static and moving patterns

- ***Data mining*** is about finding patterns that were previously unknown or that depart from the norm.
  - New field of ***visual analytics***
- When we look for patterns, we are making ***visual queries*** that are key to visual thinking.
- In data exploration, seeing a pattern can often lead to a key insight, and this is the most compelling reason for visualization.

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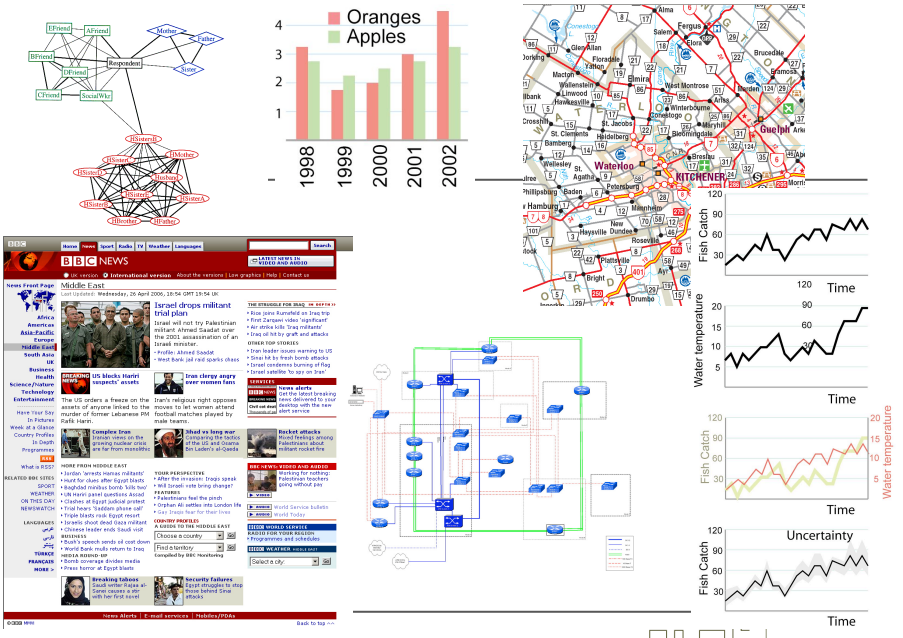

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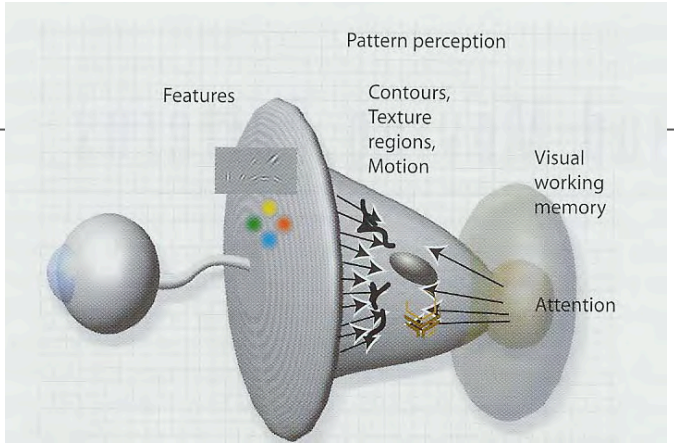


- Figure 6.1 Pattern perception forms a middle ground where the bottom-up processes of feature processing meet the requirements of active attention.

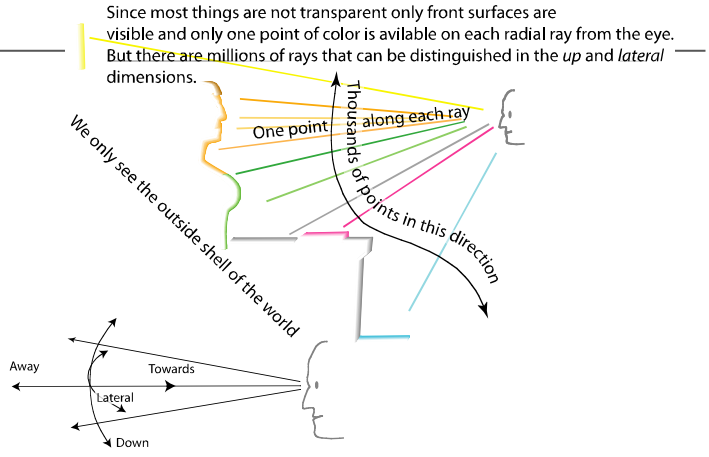
Pattern perception

- In the early stages, massively parallel processing of the entire image occurs.
- This drives perception from the bottom up.
- Object and visual search recognition is driven from the top down through active attention, meeting the requirements of ***visual thinking***.
- Pattern perception is the flexible middle ground where objects are extracted from patterns of features

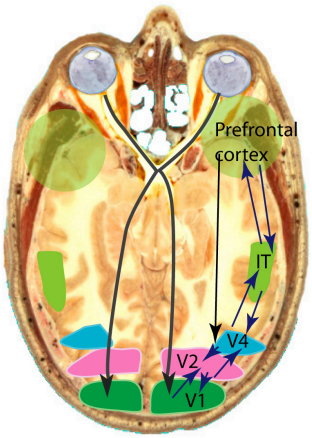
Pattern perception

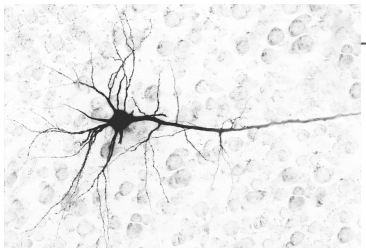
- Pattern perception is the flexible middle ground where objects are extracted from patterns of features
  - At the top level, only three to five objects (patterns) are held in visual working memory
- Understanding pattern perception provides abstract design rules on how to organise data so important structures are perceived
  - If we can map **information** structures to **readily perceived patterns** then those structures will be more easily interpreted
- Learning is important
  - ***Priming:*** once we have seen a pattern we identify it much more easily
  - ***Long-term learning:*** takes place over thousands of occurrences, but some patterns are much easier to learn (quicker) than others

The dimensions of space



The “What” Channel





Patterns of patterns

Two parts

- Part I: Static Patterns
- Part II: Patterns in Motion

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Gestalt psychology

- The first serious attempt to understand pattern perception (1912) was the Gestalt school of psychology.
  - [Max Westheimer, Kurt Koffka, and Wolfgang Kohler (1912)]
  - The word *gestalt* simply means *pattern* in German.
- Idea: forms or patterns transcend the stimuli used to create them.
  - Why do patterns emerge?
  - Under what circumstances?
- They produced a set of Gestalt principles of pattern perception.
  - Original proposed mechanisms turned out to be wrong
  - Rules themselves are still useful

Gestalt laws

- These are robust rules that describe the way we set patterns in visual displays, and although the neural mechanisms proposed by these researchers to explain the laws have not withstood the test of time, the laws themselves have proved to be of enduring value.
- The Gestalt laws easily translate into a set of design principles for information displays.

The Gestalt laws

The core laws

1. Proximity
2. Similarity
3. connectedness
4. Continuity
5. Symmetry
6. Closure
7. Relative Size
8. Common fate

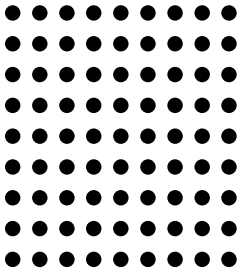
Principal effects

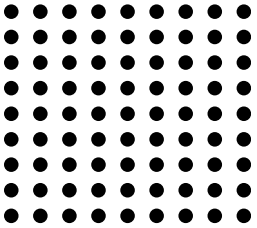
9. Figure - ground
10. Prägnanz : the “organising principle”

Proximity

- Spatial proximity is a powerful perceptual organizing principle and one of the most useful in design.
- Things that are close together are perceptually grouped together.
- The application of the proximity law in display design is straightforward: the simplest and most powerful way to emphasize the relationships between different data entities is to place them in proximity in display.

Proximity





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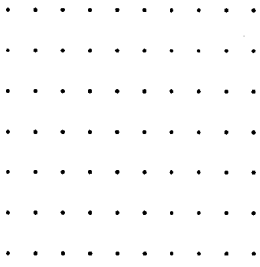
Proximity



rows

columns

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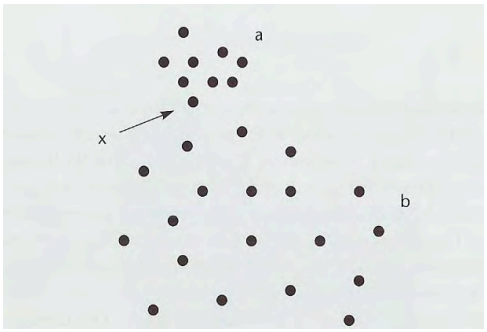
Proximity

- We are more likely to associate the lines which are close together than those which are further apart. In this example we tend to see three pairs of lines which are fairly close together (and a lonely line on the far right) rather than three pairs of lines which are further apart (and a lonely line on the far left).

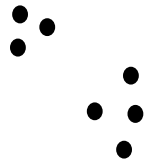
Proximity and density

- **Principle of spatial concentration**. Dot x is perceived as part of group a rather than group b although it is equidistant
- We perceptually group **regions of similar density**

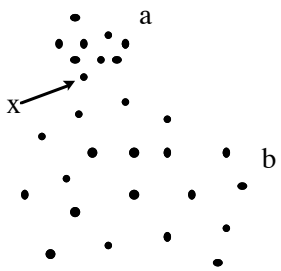


Proximity: design implications

- Emphasize relationship by proximity



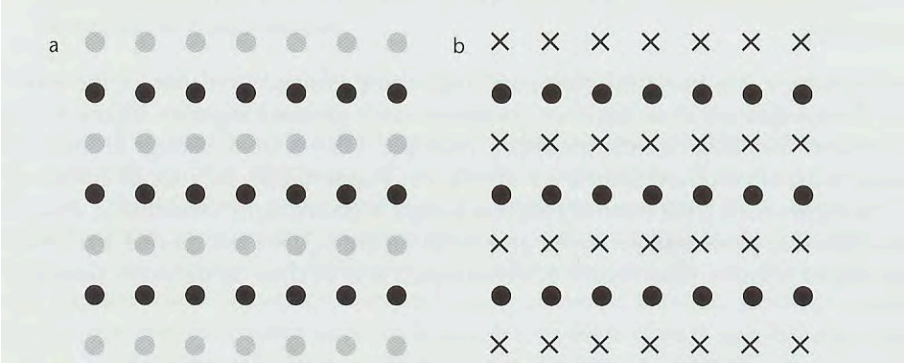
- Emphasize relationship by spatial density



Similarity

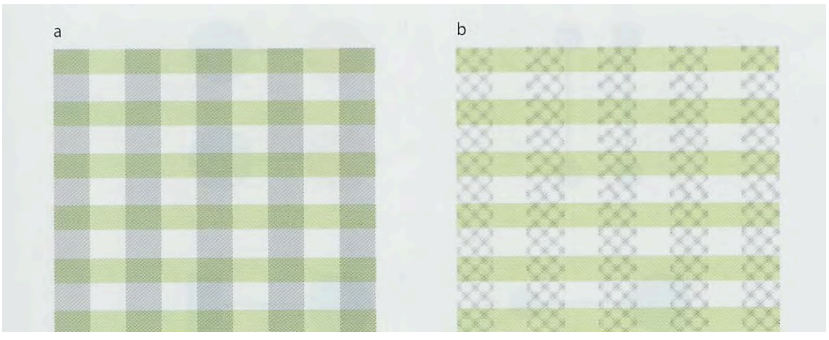
- The shapes of individual pattern elements can also determine how they are grouped
- Similar elements tend to be grouped together

Similarity



- Similarity between the elements in alternate rows causes the **row percept** to dominate

Similarity and integral dimensions

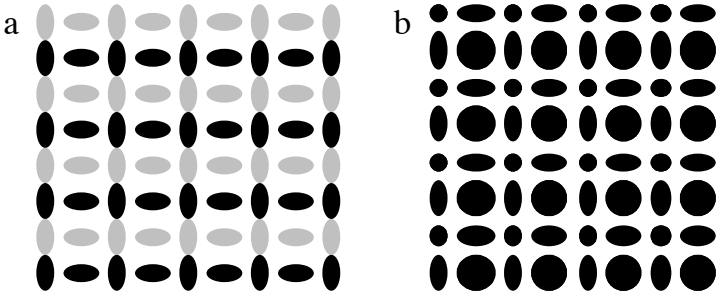


(a) Integral dimensions (colour and grayscale) are used to delineate rows and columns
(b) Separable dimensions (colour and texture) make it easier to attend separately to either the rows or the columns

Similarity and integral dimensions

separable

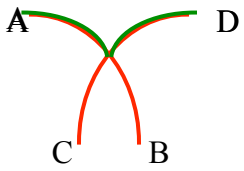
integral



- A: separable dimensions allow both groupings to be perceived – but not simultaneously
- B: we can see both to construct a grid

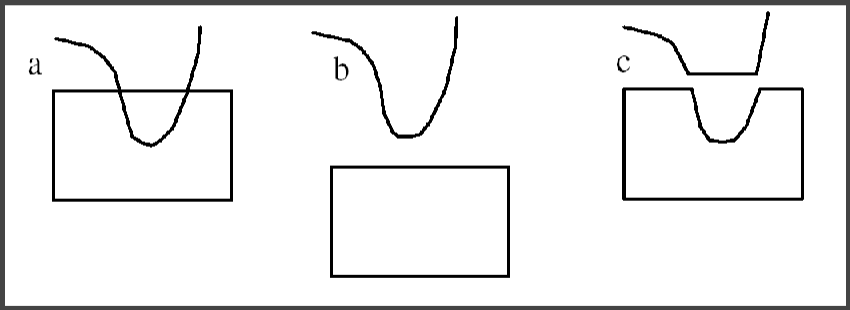
Continuity

- The Gestalt principle of continuity states that we are more likely to construct visual entities out of objects that are smooth and continuous, rather than those that contain abrupt changes in direction.
- We see a-b crossing c-d
- not a-d or b-c



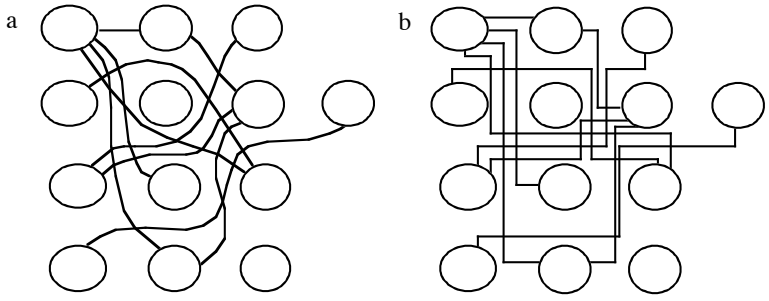
Continuity

smooth not abrupt change
overrules proximity



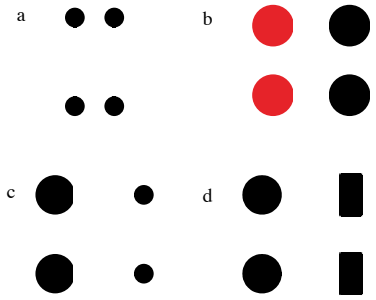
Continuity in Diagrams

- Connections using smooth or abrupt lines
- Which is easier to follow?



Connectedness

- Connectedness can over-rule **proximity**, colour, size or shape



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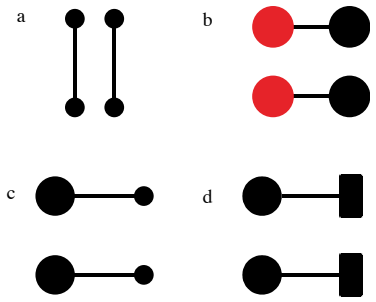
Connectedness

- Connecting graphical objects by a line is a very powerful way of expressing that there is a relationship between them



- Basis of node-link diagrams
- Most common method of indicating relationships

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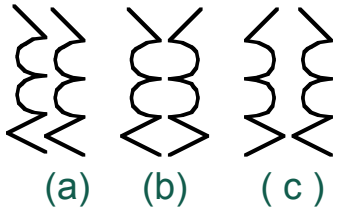
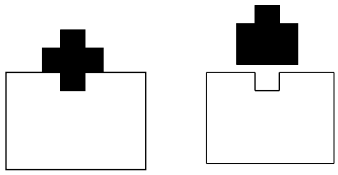
Symmetry

- Symmetry creates **visual whole**
- Powerful organising principle
- b and c are seen as figures/objects, where a is a pair of parallel lines
- We construct objects in the world



Symmetry

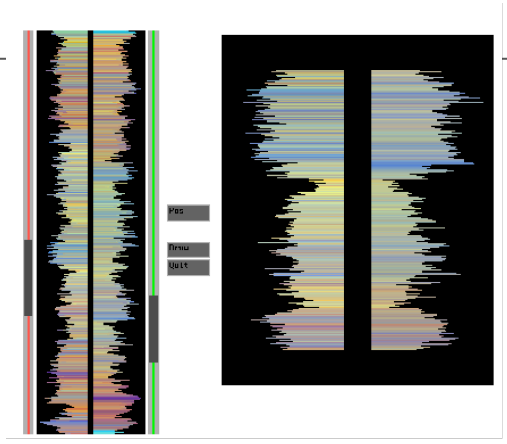
- Symmetry creates visual whole
- Powerful organising principle
- Outlines and filled shapes
- We see a cross in front of a rectangle not the second option



Symmetry

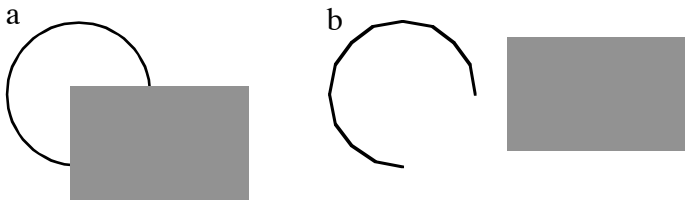
- Possible application is in tasks where data analysts are looking for similar patterns (e.g. in time-series data).
  - Detect **asymmetries** effectively

Symmetry (cont.)



Closure

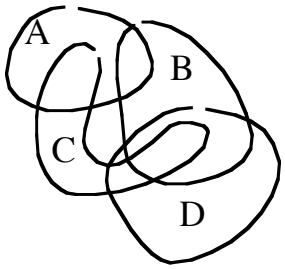
- Over-rules proximity
- A closed contour tends to be seen as an object
- The Gestalt psychologists argued that there is a perceptual tendency to close contours that have gaps



a circle behind a rectangle as in (a), not a broken ring as in (b).

Closure (cont.)

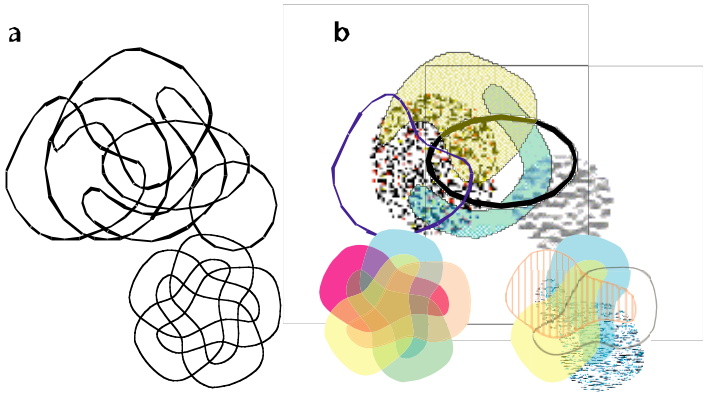
- Closed contours to show set relationship
- An Euler diagram. This diagram tells us (among other things) that entities can simultaneously be members of sets A and C but not of A, B, and C.
- Also, anything that is a member of both B and C is also a member of D.
- These rather difficult concepts are clearly expressed and understood by means of closed contours.



Closure

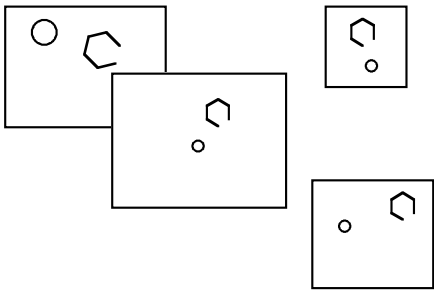
- Wherever a closed contour is seen, there is a very strong perceptual tendency to divide regions of space into “inside” or “outside” the contour.
- A region enclosed by a contour becomes a common region [Palmer (1992)].
- **Common region is a much stronger organising principle than simple proximity**
- This is presumably the reason why Venn-Euler diagrams are such a powerful device for displaying associations among sets of data.

Extending the Euler diagram



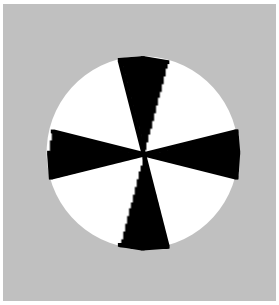
Closure

- Rectangular contours strongly segment the visual field.
- Creating frame of reference
- Position of objects judged based on enclosing frame
- Where is this critical?



Relative Size

- Smaller components tend to be perceived as objects
- prefer horizontal and vertical orientations

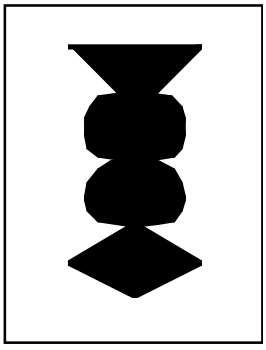


Gestalt organising principles

- Figure and ground
- Subjective contour
- Prägnanz

Figure and Ground

- Confronted by a visual image, we seem to need to separate a dominant shape (a 'figure' with a definite contour) from what our current concerns relegate to 'background' (or 'ground')
- Symmetry, white space, and closed contour contribute to perception of figure.
- **The perception of figure as opposed to ground can be thought of as the fundamental perceptual act of identifying objects**.



Figures and Grounds

Rubin's Vase

- Competing recognition processes trying to construct objects from the pattern
- One basis of trompe l'oeil

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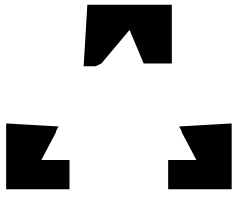
Subjective Contour

- We construct an object from pieces



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Emergence

- (Kosara)
- Holistic perception of image

Prägnanz

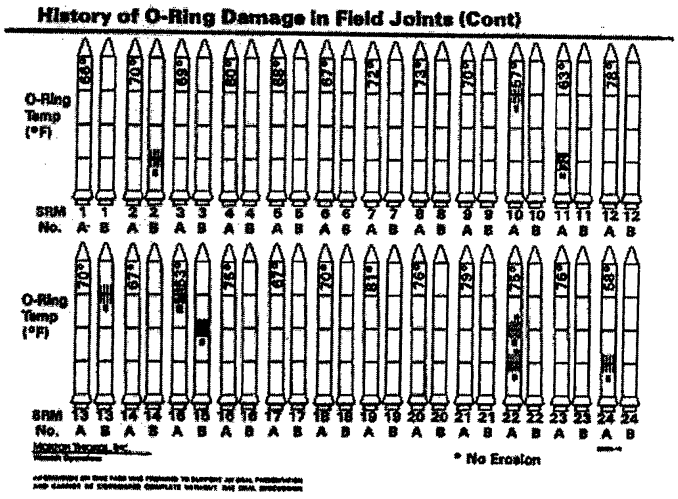
- The law of “good form”
- Overarching principle that the simplest and most stable interpretations are preferred
- “What the Gestalt principles of perceptual organization suggest is that we may be predisposed towards interpreting ambiguous images in one way rather than another by universal principles…The Gestalt principles can be seen as reinforcing the notion that the world is not simply and objectively 'out there' but is constructed in the process of perception.”
  - --Daniel Chandler
- http://www.aber.ac.uk/media/Modules/MC10220/visper07.html

Prägnanz

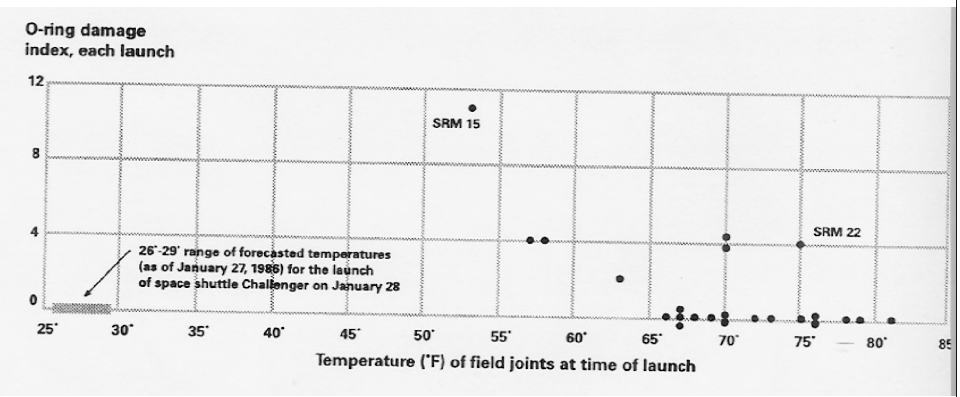
- A stimulus will be organized into as good a figure as possible. Here, good means symmetrical, simple, and regular.
- here we see a square overlapping a triangle, not a combination of several complicated shapes.

Design example

Does this point out relationships?



Same Data – Different Plot



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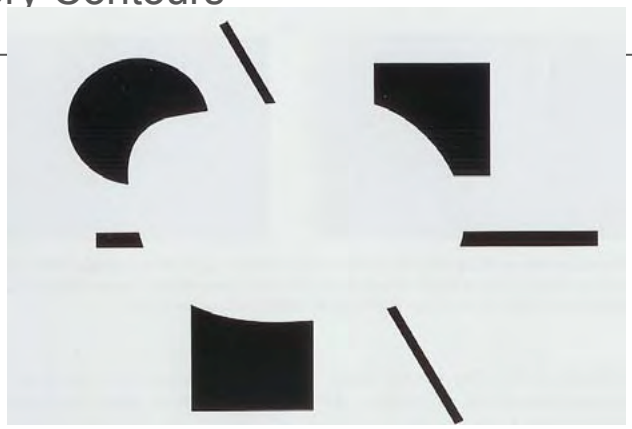
More on Contours

- A contour is a continuous perceived boundary between regions of a visual image.
- A contour can be defined by a line, by a boundary between regions of different color, by stereoscopic depth, by motion patterns, or by texture.
- Contours can even be perceived where there are none.

Illusory Contours



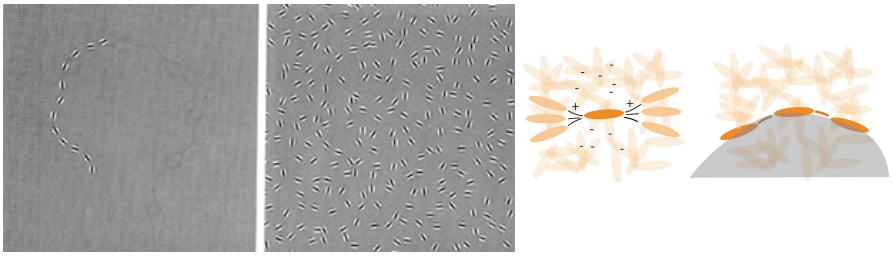
- an illusory contour; a ghostly boundary of a blobby shape is seen even where none is physically present.

Contour perception

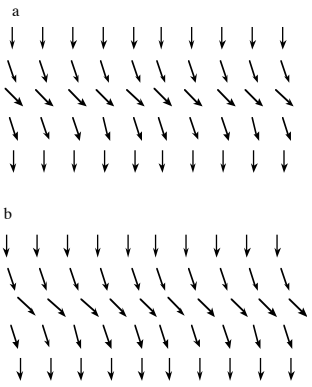
- We don't understand contour perception very well
- Suggestion that our receptors fire all together and that is how we"hold" contours in mind
- Circumstances of contour perception and good continuity empirically validated

Field, Hayes and Hess

Contour finding mechanisms



More Contours



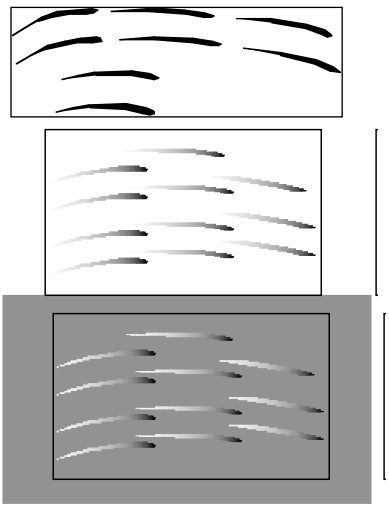
- Direct application to vector field display
- Should be easier to perceive if smooth (i.e. **continuous**) lines can be drawn through the arrows
- b is more effective than a

Perceiving Direction: representing vector fields

- The perception of contour leads us naturally to the perceptual problem of representing vector fields.
  - Vector fields used to show flow
  - Currents, winds, fluid
- This problem can be broken down into two components: the representation of orientation and the representation of magnitude.
- Some techniques display one component but not both

Vector fields

- Contours and pen strokes, 3D, shading
- Interaction between direction of colour change and background colour
- Away from bg colour
- In Ware's exps, colour change direction dominated shape



Flow field visualisation

- Identify location and nature of critical points
- Judge *advection* trajectory
  - Path taken by a dropped particle
- Patterns of high and low velocity
- Patterns of high and low vorticity
- Patterns of high and low turbulence

Many algorithms

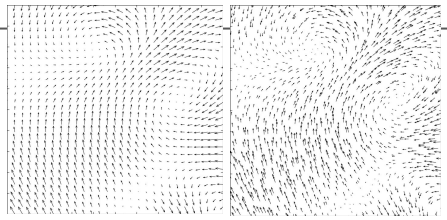
- Optimizing trace density (poisson disk)
- Flexible methods for rendering (enhanced particle systems).

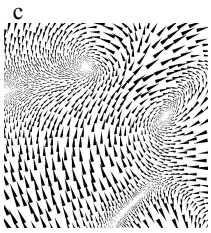
Evaluation

- Direction
- Magnitude
- Advection
- Global pattern
- Local pattern
- Nodal points

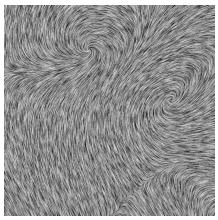
Vector Field Visualization

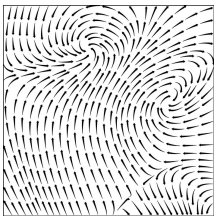
Least effective for critical points

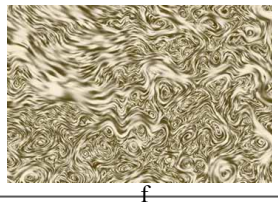




- Many different algorithms to generate flow diagrams

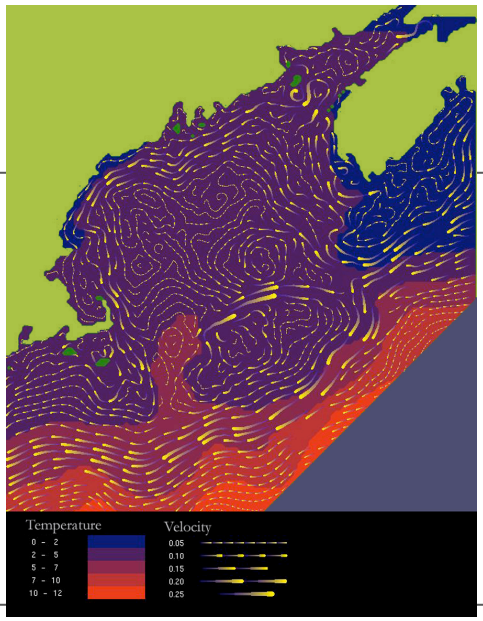






Best for advection

Laidlaw



- Problem is less one of choosing the algorithm and more one of optimising visual parameters (colour, grey value, length, width,shape)

Transparency and layering

- In many visualization problems, it is desirable to present data in a layered form.
- This is especially common in geographic information systems (GISs).
- Sometimes, a useful technique is to present one layer of data as if it were a transparent layer over another.

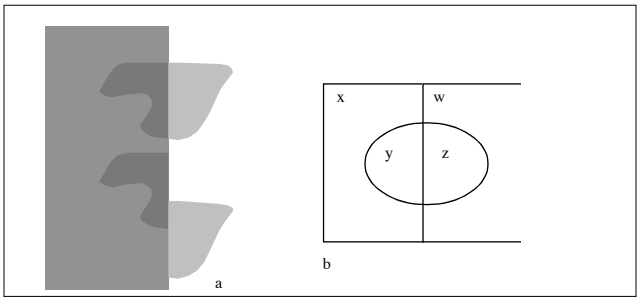
Transparency and layering

- However, there are many perceptual pitfalls in doing this.
- The contents of the different layers will always interfere with each other to some extent, and sometimes the two layers will fuse perceptually so that it is not possible to determine to which layer a given object belongs.

Transparency

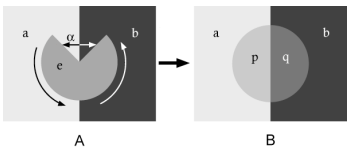
Continuity is important in transparency

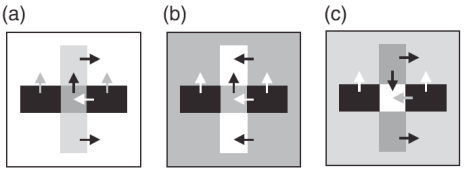
- Ratio of colour or grey
  - x < y < z or x > y > z
  - y < z < w or y > z > w



Transparency remains an active question

- Rotating disk with gaps – luminance integration
- (Metelli)
- Direction of contrast – Xjunctions
- (Cavanaugh)

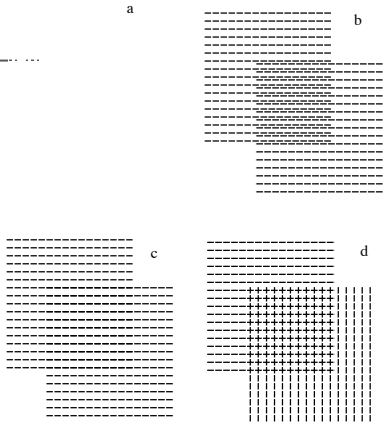




Laciness (Cavanaugh)

- Layered data: be careful with composites of textures
- Similar patterns perceptually interfere (last week)
- Overlay menus and images need perceptually strongly distinct channels

b is a distinct patch



c is one, d is "bistable"

Pattern learning

- Can we learn to see patterns better?
- What is the scientific evidence that people can learn to see patterns better?
- The results are mixed.
- There have been some studies of pattern learning where almost no learning occurred.
- But other studies have found learning for certain patterns.

Pattern learning

- A plausible explanation is that pattern learning occurs least for simple, basic patterns processed early in the visual system, and most for complex, unfamiliar patterns processed late in the visual system.
- What are the implications of these findings for visualization?

Pattern learning

- One is that people can learn pattern-detection skills, although the ease of gaining these skills will depend on the specific nature of the patterns involved.
- Experts do indeed have special expertise.
  - The power law of practice
- The radiologist interpreting an X-ray, the meteorologist interpreting radar, and the statistician interpreting a scatter plot will each bring a differently tuned visual system to bear on his or her particular problem.

Pattern learning

- People who work with visualizations must learn the skill of seeing patterns in data.
- In terms of making visualizations that contain easily identified patterns, one strategy is to rely on pattern-finding skills that are common to everyone.
- Good idea to use *priming* to enhance perceptual receptivity