Visual Thinking

Structuring Two-Dimensional Space

Higher level order: Patterns

- ideas+ physical evidence = pattern
- patterns are the essence of visual thinking
  - often to perceive a pattern is to solve a problem
- **patterns** are formed from low-level features
  - the building blocks of **objects**
  - or relationships between objects
- understanding how patterns are formed can inform the task of organising space:
  - unambiguous and clear

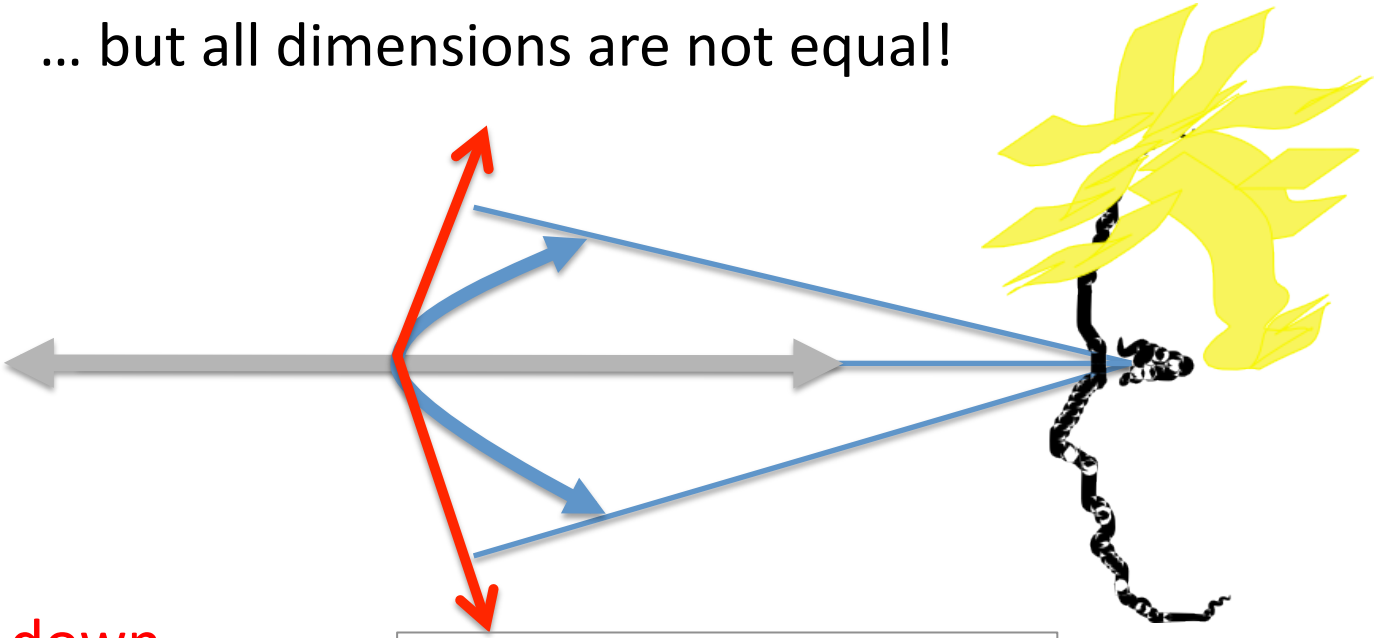
  versus
  - multiple interpretations

multiple interpretations

Space

- We live in a 3D world….

  … but all dimensions are not equal!



- up-down
- sideways
- towards-away

Actually more like 2.5 dimensions, where the 0.5 is the *away* dimension

or even 2.05 dimensions!

image plane + depth

Space again

- To get information in up-down and sideways planes, we can rapidly sample with our eyes
- But to get information about depth, we need to move.

- Image plane sampling is 10-100x more efficient than depth sampling
- Pattern processing in the brain is mostly devoted to the image plane.

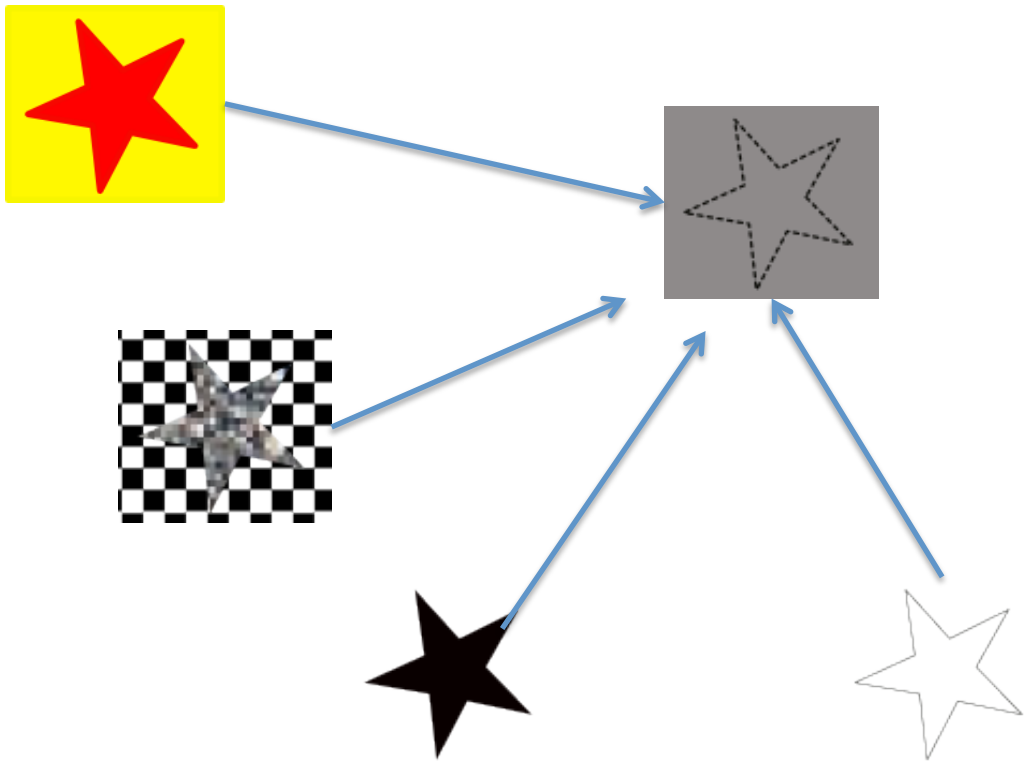
Pattern examples

Pattern Processing Machinery

- two kinds of processes involved in pattern perception:
  1. dividing up-down space through binding of contours and areas
     - process of indentifying parts of the same region are called ***binding***
       - » makes disconnected pieces of information connected
       - » edge detector neurons
  2. 'what' pathway – processes patterns to ultimately identify objects

Generalized Contour

our brains have a *contour extraction mechanism*



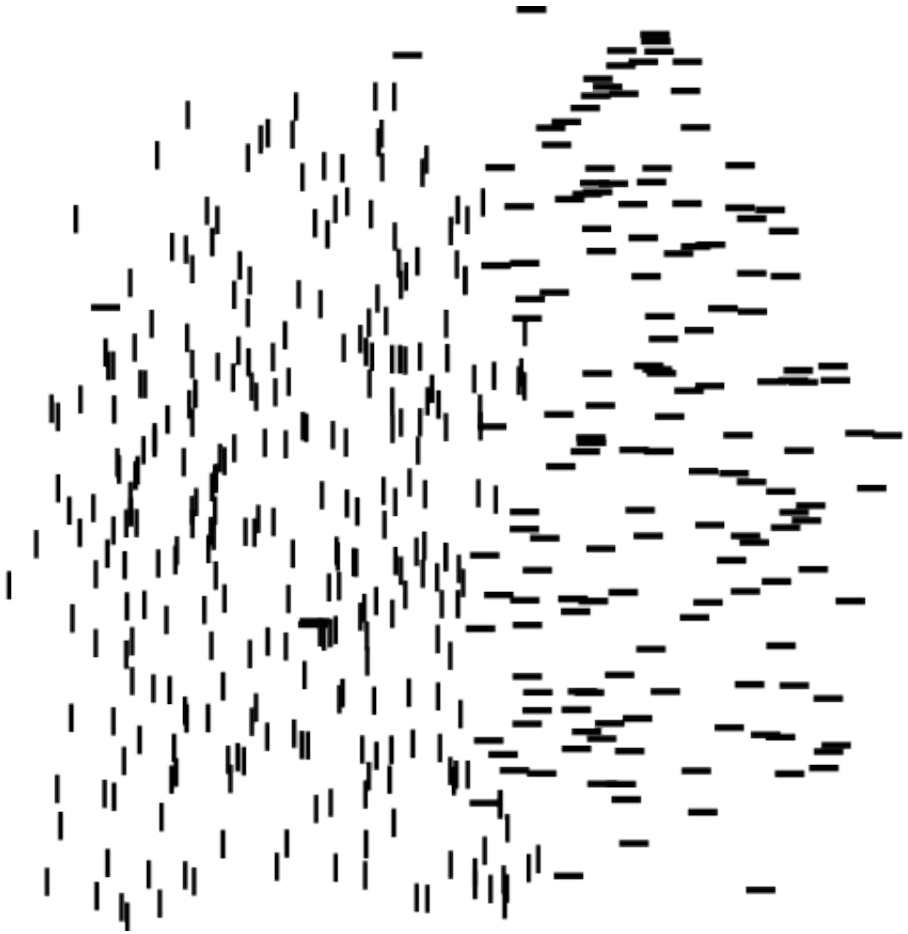
Many different kinds of boundaries activate a generalized contour

This is why line drawings are so effective.

Texture regions

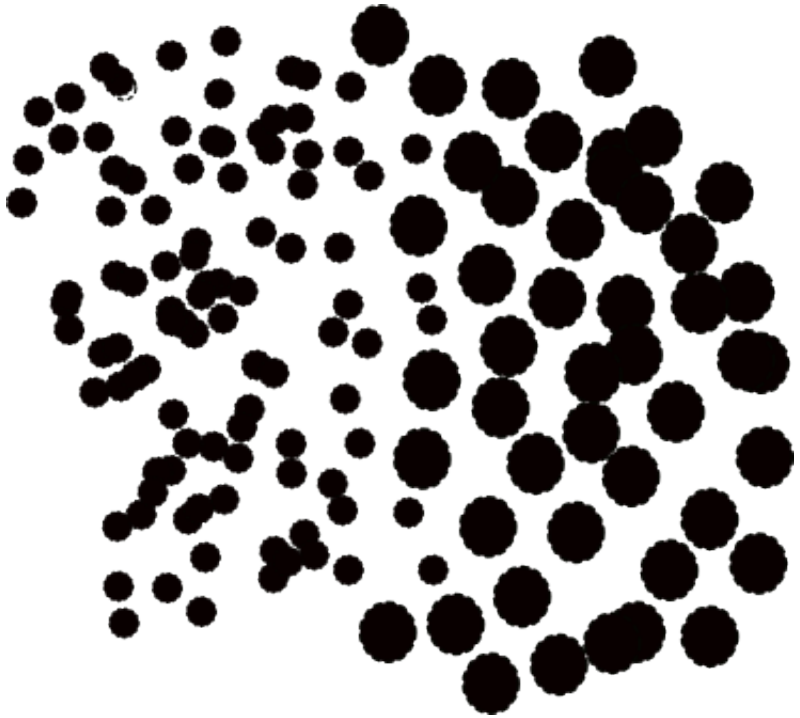
- Texture is distinguished in the same way at single objects – primary factors are grain size, orientation and contrast

Textures that are easy to distinguish



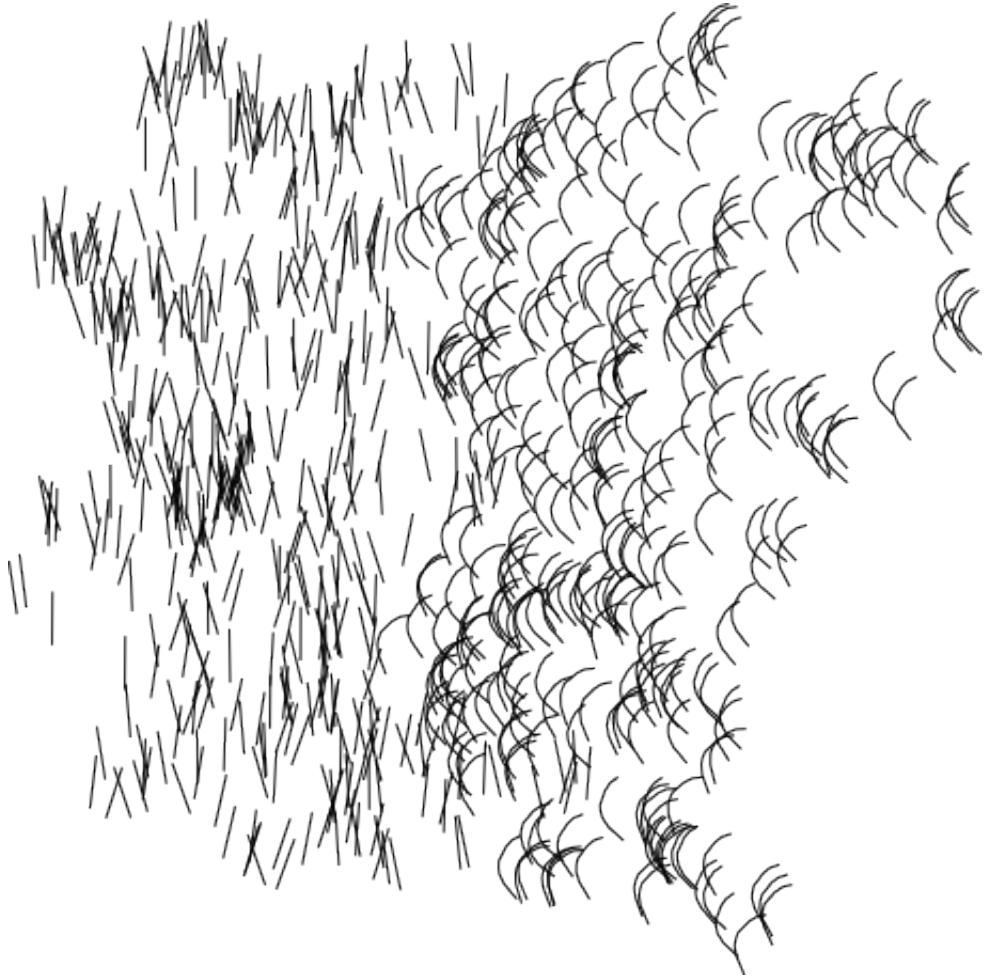
orientation

Textures that are easy to distinguish



grain size

Textures that are easy to distinguish



curved versus straight

Textures that are easy to distinguish

sharp versus blur

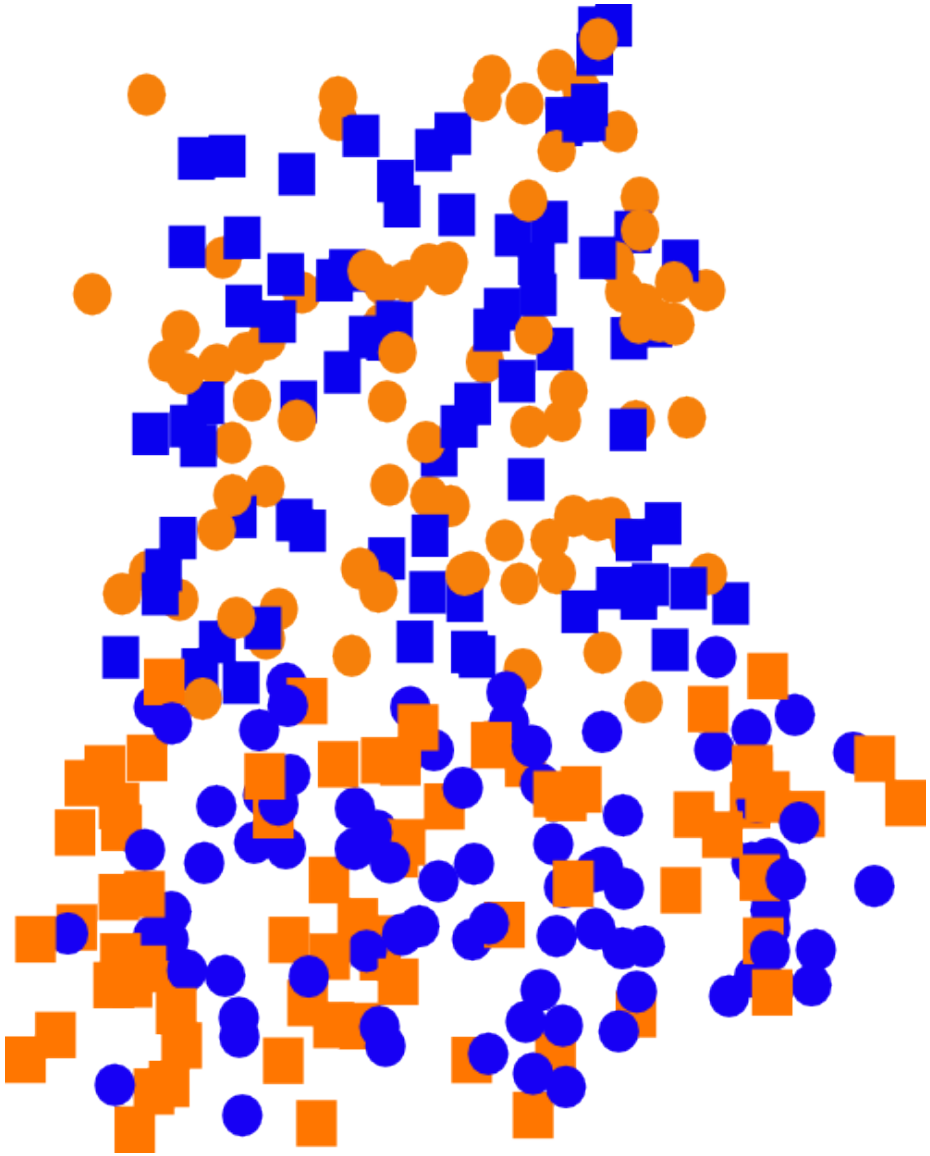
Hard-to-discriminate texture pairs

- when low-level feature differences not present, we find it hard to discriminate between textures
- for design purposes, only basic texture differences should be used to divide space

Hard-to-discriminate texture pairs

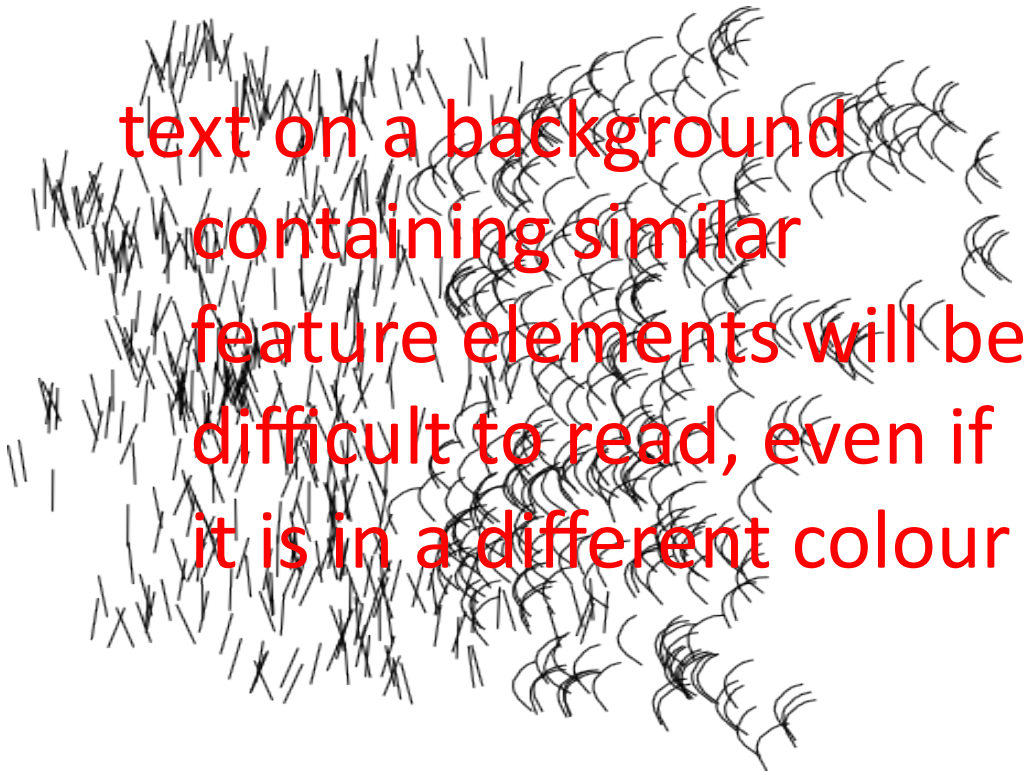
spikes orientated differently, but field of orientation is same

Hard-to-discriminate texture pairs

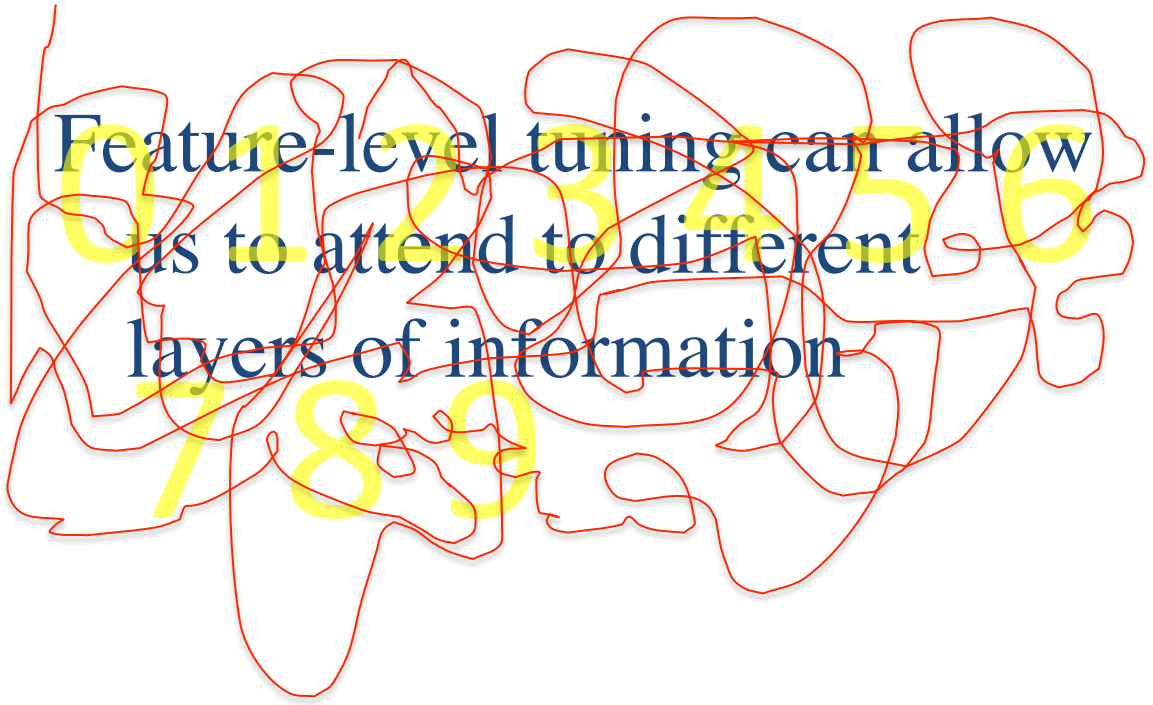


orange circles and blue squares versus blue circles and orange squares

Interference



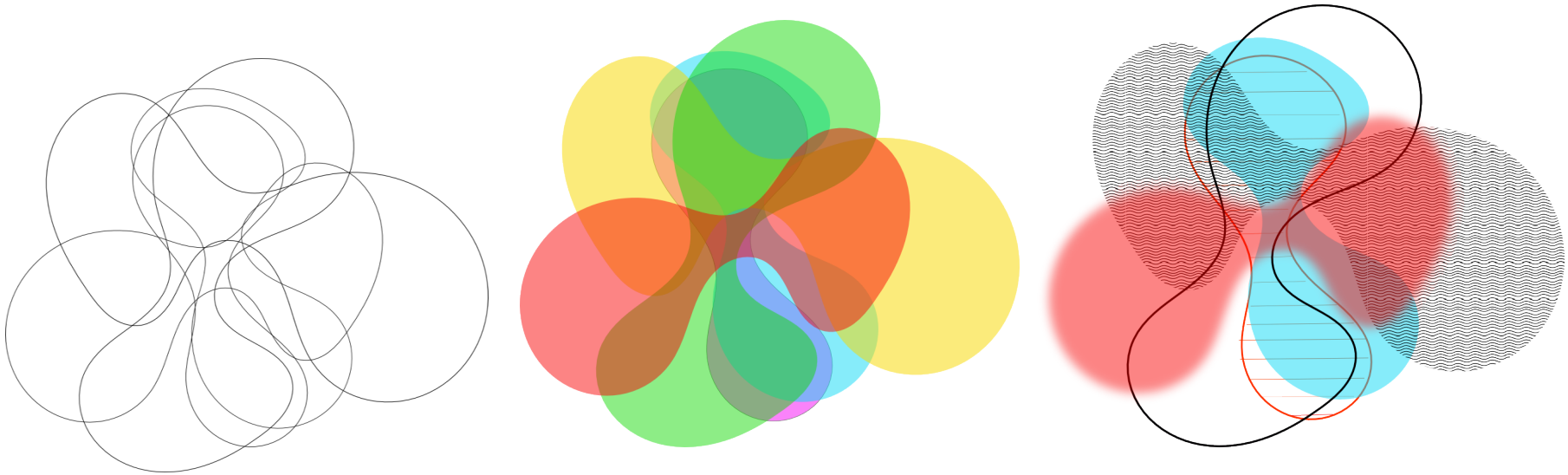
Feature-level tuning



Feature-level tuning for overlapping regions

- Representing overlapping regions is an interesting design problem
  - e.g. a map that shows both mean temperature, differing vegetation types etc.
  - Goal is to support variety of queries based on temperature zones, vegetation zones or both.
  - if different regions are display to be as distinct as possible in terms of simple features, the result will be easy to interpret

Feature-level tuning for overlapping regions: example



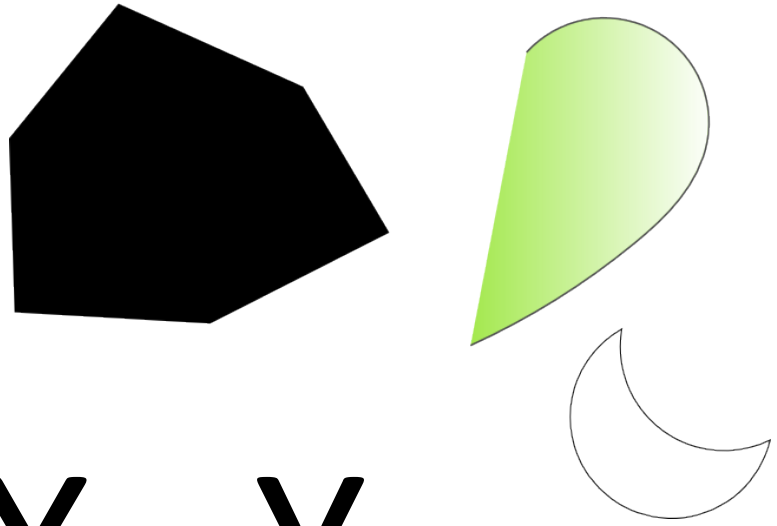
heterogeneous channel-based approach

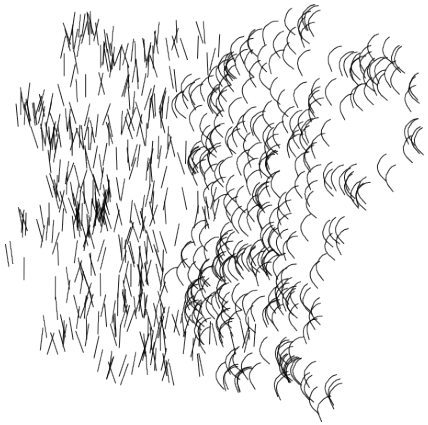
What are the best patterns?

- The *what* pathway identifies patterns, which are increasingly complex the further we move up the hierarchy
- There is no current experiment that will determine which, of a possible infinite number, patterns a neuron responds to best
  - all researchers can do currently is find out by trial and error which patterns humans respond to well

What are the best patterns?

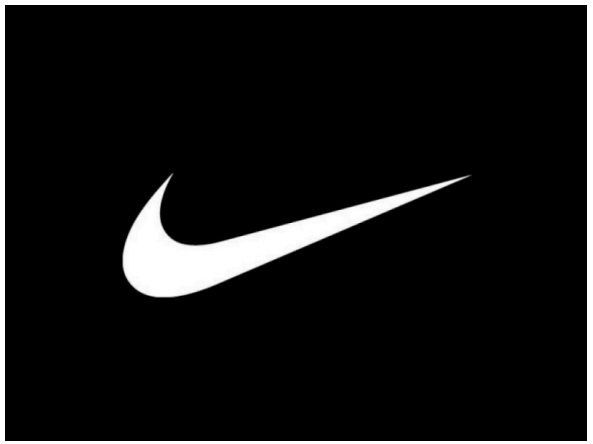
- spikes
- convexities and concavities
- boundaries between texture regions
- T and X junctions





T X Y

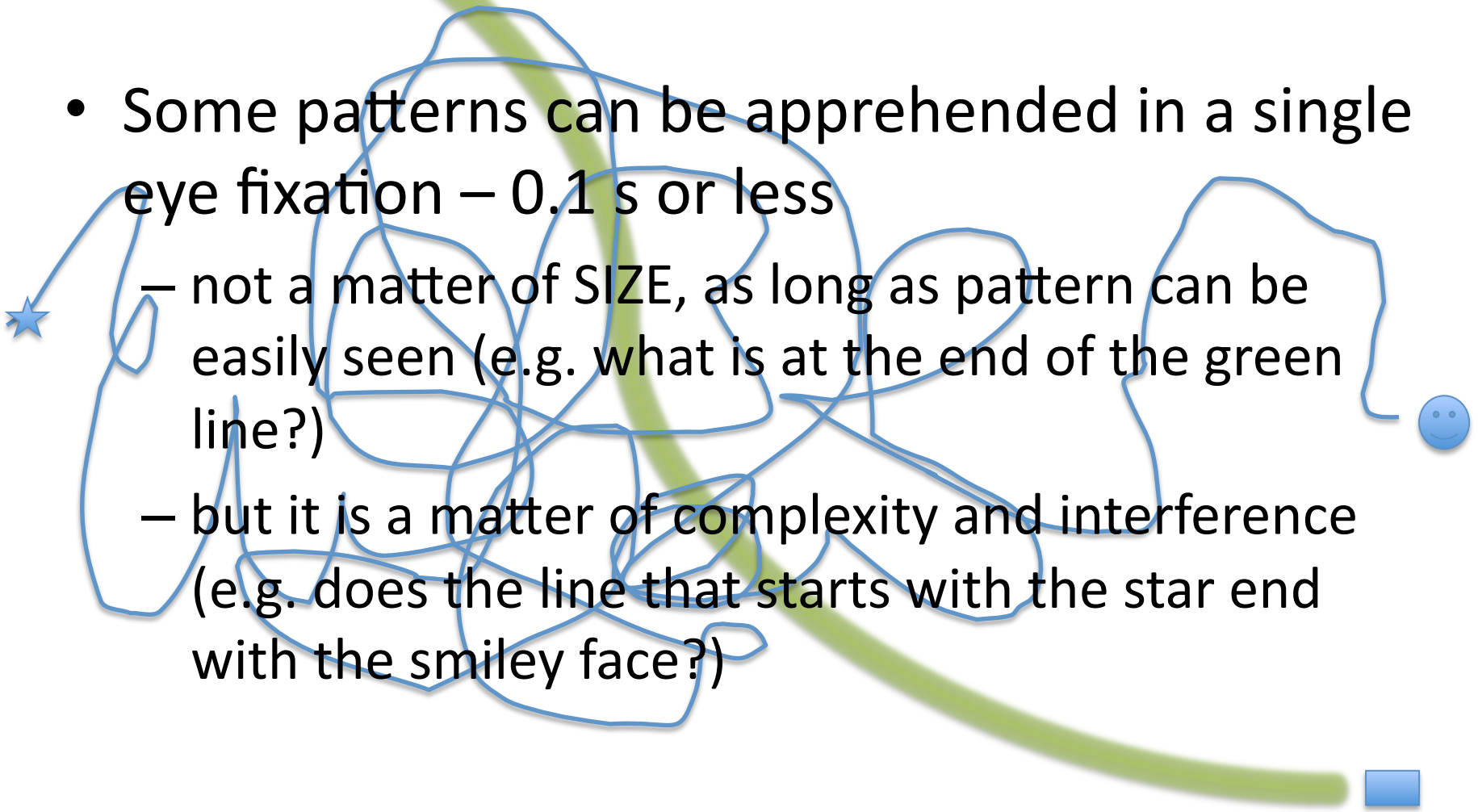
Natural selection for symbols?



The importance of experience

- As we move up the “what” pathway to more complex patterns, the effects of individual experience become apparent
  - much of the training in V1 happens in babies
  - higher up the pathway is later life training

Apprehendable chunk



- Some patterns can be apprehended in a single eye fixation – 0.1 s or less
  - not a matter of SIZE, as long as pattern can be easily seen (e.g. what is at the end of the green line?)
  - but it is a matter of complexity and interference (e.g. does the line that starts with the star end with the smiley face?)

Apprehendable chunk

- The scribble query requires several eye fixations – several apprehendable chunks
  - for **unlearned** patterns, the size of the apprehendable chunk is about three feature components
  - when a pattern has more than one apprehendable chunk, visual queries are broken up into sub queries

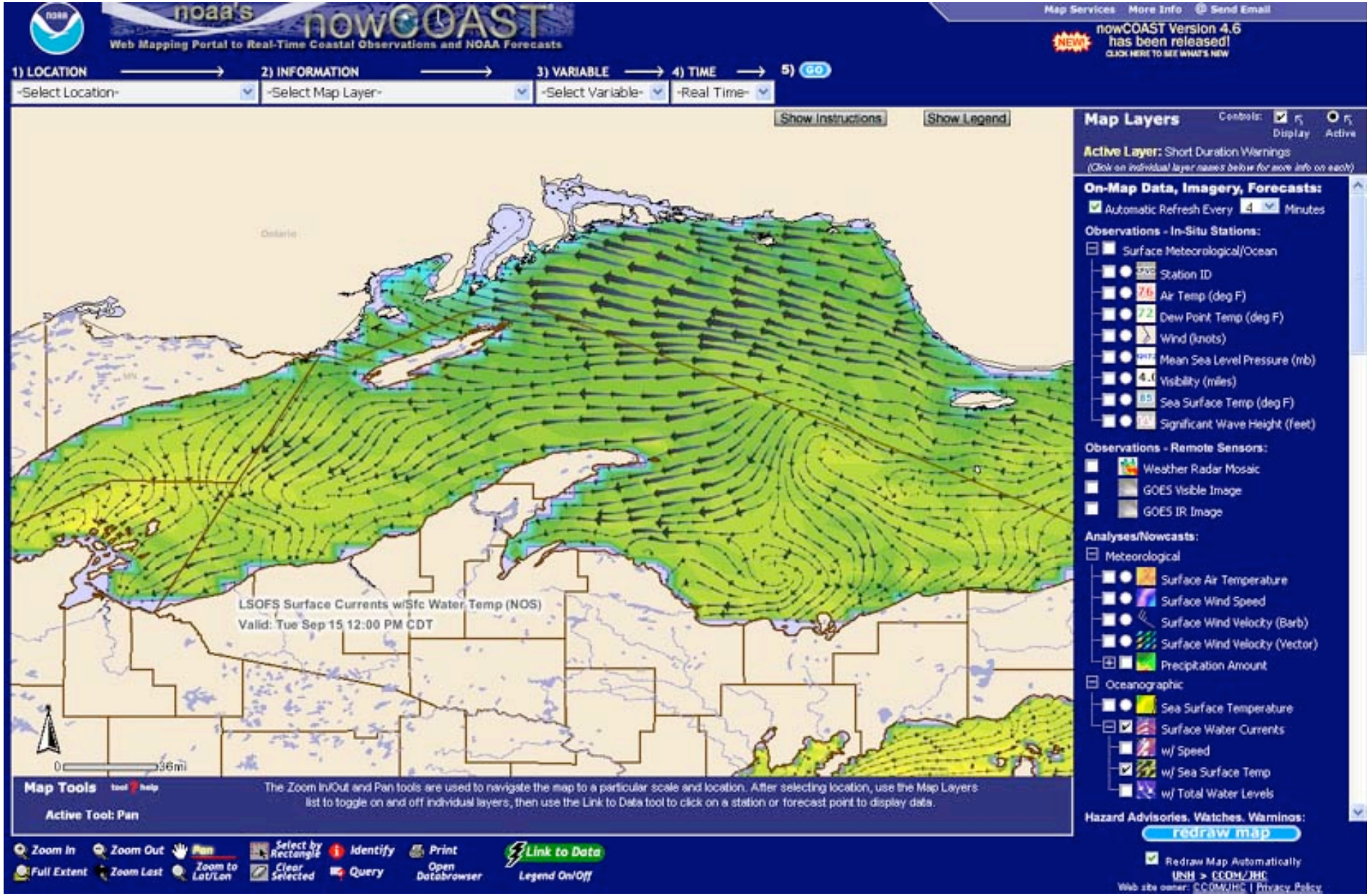
Semantic meaning of patterns
Basic patterns

- small shapes with closed contour :
  - object, idea, entity, node
- Spacial ordered graphical objects:
  - related information or a sequence (left-to-right)
- Objects in proximity or with same colour/texture:
  - similar concepts, related information
- Size or height of object:
  - Magnitude, quantity, importance, 2D location

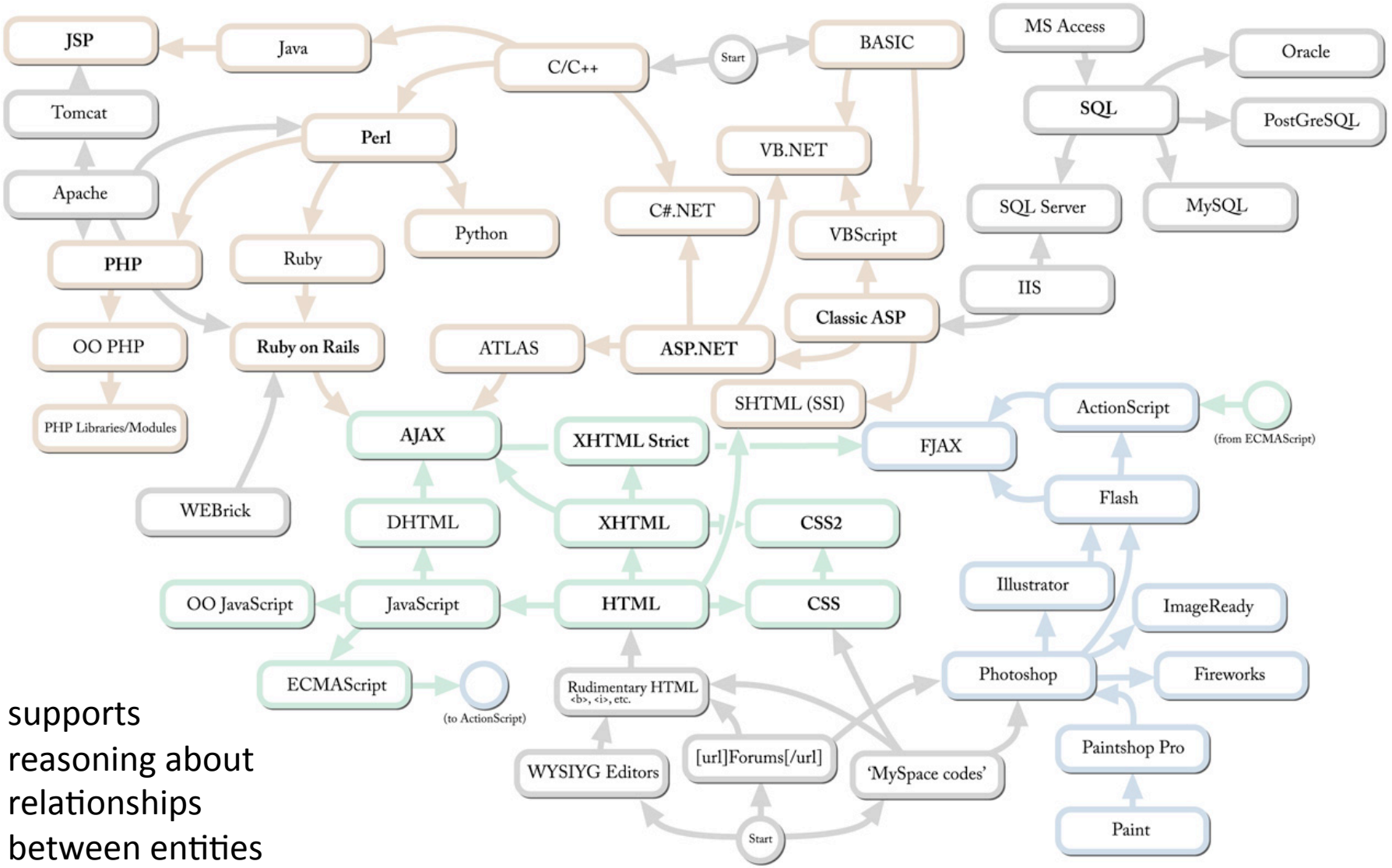
Semantic meaning of patterns
More complex patterns

- Shapes connected by contour:
  - related entities, path between entities
- Thickness of connecting contour:
  - strength of relationship
- Colour and texture of connecting contour:
  - type of relationship
- Shapes enclosed by a contour/texture/colour:
  - contained entities, related entities
- Nested/partitioned regions:
  - hierarchical concepts
- Attached shapes:
  - parts of a structure

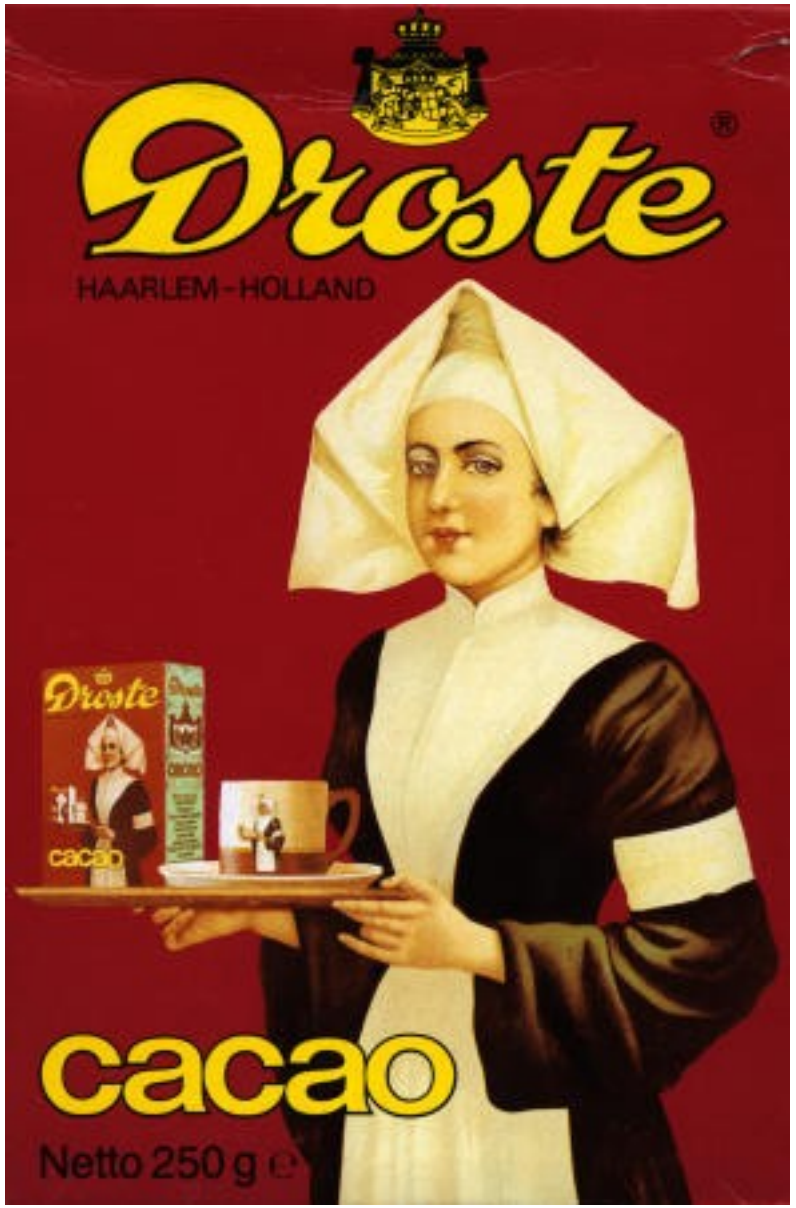
Screenshot of nowCOAST Viewer, showing detailed view of the Lake Superior OFS Surface Water Currents nowcast. The background colors shown indicate Sea Surface Temperature.



node –link diagram



supports
reasoning about
relationships
between entities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