**Computer Vision**

Computer Science Tripos Part II

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**Gestalt Theory**

- Gestalt: a meaningful “whole” or “group”
  - Whole is greater than the sum of its parts
  - Relationships among parts can yield new properties/features

- Psychologists identified a series of principles (laws) of perceptual organisation
  - “I stand at the window and see a house, trees, sky. Theoretically I might say there were 327 brightnesses and nuances of colour. Do I have “327”? No. I have sky, house, and trees.”
  - Max Wertheimer (1880-1943)

http://psy.asu.edu/~classics/Wertheimer/Forms/forms.htm

**Gestaltism**

Perception results from the interaction between the intrinsic structure of the stimulus and the intrinsic structure of the brain.

Max Wertheimer

Wolfgang Köhler

Kurt Koffka

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**Principles of Gestalt Theory**

- Holism: The whole is different from the sum of its parts.
- Prägnanz: (saliency, conciseness) The percept will be as “best” as the prevailing conditions allow, i.e. simplest explanation.
- Nativism: Not a total rejection of learning, but rejection of its primacy.
Holism: The whole is different from the sum of its parts.

Emergent properties:
Features of a configuration that are not features of its components, e.g.:
- length
- orientation
- curvature
- closure
- connectedness

Prägnanz: the percept will be as "good" as the prevailing conditions allow

What is this? square & circle? square & pacman? squig & pacman? etc....

Principles of Perceptual Organisation

Koffka noted in 1935:

"...to apply the Gestalt category means to find out which parts of nature belong as parts to functional wholes, to discover their position in these wholes, their degree of relative independence, and the articulation of larger wholes into sub-wholes."

Max Wertheimer

"There are wholes, the behaviour of which is not determined by that of their individual elements, but where the part-processes are themselves determined by the intrinsic nature of the whole (...) This problem cannot be solved by listing possibilities for systematisation, classification, and arrangement. If it is to be attacked at all, we must be guided by the spirit of the new method and by the concrete nature of the things themselves which we are studying, and yet ourselves to penetrate to that which is really given by nature."

Influences of grouping
The importance of **context**

Examples:
- Collinearity
- Smoothness
- Symmetry
- Parallelism
- Cotermination

Colinear points are not generally a consequence in a random set of points. Collinearity is a consequence of the number of points present.

**Examples:**
- Colinearity
- Smoothness
- Symmetry
- Parallelism
- Cotermination

The high speed and accuracy of determining a given non-accidental relation (e.g., whether some pattern is symmetrical) should be contrasted with performance in making absolute quantitative judgments of variations in a single physical attribute, such as length of a segment or degree of tilt or curvature.

Object recognition is performed by humans in around 100ms or less.

"If contours are deleted at a vertex they can be restored, as long as there is no accidental filling-in. The greater disruption from vertex deletion is expected on the basis of their importance as diagnostic image features for the components."
**Vision as Language**

- From signals to symbols
- Syntax and semantics

<table>
<thead>
<tr>
<th>Nouns:</th>
<th>Verbs:</th>
<th>Prepositions:</th>
</tr>
</thead>
<tbody>
<tr>
<td>objects</td>
<td>actions</td>
<td>spatial, temporal etc. relations</td>
</tr>
</tbody>
</table>

- From signals to symbols
- Syntax and semantics

**Vision as Inference**

- Uncertainty and complexity
- Formulation of hypotheses -> degrees of belief
- Integration of prior knowledge
- Iterative integration of new knowledge
- Causal reasoning, conditional dependence and independence
- Bayesian networks

\[
p(H|D) = \frac{p(D|H)p(H)}{p(D)}
\]

**Constructivism**

Constructivism: Perception is the result of unconscious inferences about the scene most likely to have caused the retinal image or event.

Hermann von Helmholtz originated the idea of unconscious inference and the likelihood principle.

Aoccdrnig to rscheearch at Cmabrigde Unervtisy, it deosn’t mtaer in what orde rh itteers in a wrod are, the olny iprmoetnt thng is that the frist and lsat ltteer be at the rghit pclae. The rset can be a total mses and you can stil raed it wouthit a porbelm. Tihs is bcuseae the huamn mnid deos not raed ervey ltteer by istlef, but the word as a wlohe.
**Constructivism**

Tilted room illusion

Unconscious Inference: the process of recovering environmental information by logically combining retinal information with heuristic assumptions.

**Tilted room illusion**: If you assume that the walls and floor of the room are vertical and horizontal, then you must be tilted — and you feel that way!

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**Likelihood Principle**: “we will perceive the object that is most likely to be the cause of our sensory stimulation” (Helmholtz)

**Hypothesis Testing**: “we may think of sensory stimulation as providing data for hypotheses concerning the state of the external world” (Richard Gregory)

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**Vision as a Cycle of Perception**

- **Hermeneutical cycle** for iterative interpretation in a generative (hypothesise and test) approach.

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**Vision as Graphics**

Richard Gregory argues this sort of illusion happens because we are not used to seeing hollow faces, and therefore our beliefs and expectations are applied to make best sense of the data.

-> top-down rather than bottom-up (as in the Marr theory)
High level interactions affect perception and processing.
Variations on the corrugated plaid. (a) The two patches appear nearly the same. (b) The patches appear quite different. (c) The patches appear quite different, but there is no plausible shaded model. (d) Possible grouping induced by junctions.

E. H. Adelson, Lightness Perception and Lightness Illusions
Richard Gregory’s “Café Wall Illusion”

Müller-Lyer Illusion

The Ames room
What is the trick?

- Viewed with one eye only
- The unusual shape of the room is not reflected in the retinal image

Depth perception arises from a variety of depth cues

Eye movement related
- Depth/distance information
- Perceptual
- Accommodation (single eye focus)
- Convergence
- Binocular disparity
- Monocular
- Static cues
- Motion parallax
- Occlusion
- Relative size
- Perspective

Eye and Brain: The Psychology of Seeing
Richard L. Gregory