Bottom-up and Top-down Perception

- **Bottom-up perception**
  - Physical characteristics of stimulus drive perception
  - Realism

- **Top-down perception**
  - Knowledge, expectations, or thoughts influence perception
  - Constructivism: we structure the world
  - “Perception is not determined simply by stimulus patterns; rather it is a dynamic searching for the best interpretation of the available data.” (Gregory, 1966)
Perceptual Illusions

**Why study illusions?**

- Illusions reveal constraints/biases on perception
  - Constraints are perceptual assumptions that we make
    - Usually correct but occasionally wrong
    - When wrong, illusion results
  - Illusions come from helpful processes
    - Without constraints, no perception at all!
  - Explore human contribution to perception by dissociating real world from our perception of it

**Case Studies**

- Railroad tracks illusion
- Apparent Motion
- Stereo depth perception
The Railroad Tracks Illusion

Assumption: the scene is taken from a 3-D world
Apparent Motion

• **Motion Perception**
  – Importance for perceptual organization
  – Dedicated brain areas

• **Apparent Motion**
  – Motion from sequentially presented still frames
  – Assume objects in one frame are the same as those in the other frame, just moved
  – Challenge: How to determine which objects correspond to each other across frames
One-to-one Mapping Constraint

Frame 1

Frame 2

Yes, horizontal motion

Yes, vertical motion

No, violates 1-to-1 mapping
Constraints on Motion Perception

- **Proximity**
  - Parts A and B tend to be the same object if they are close

- **Shape similarity**
  - Parts A and B tend to be the same object if they are similar in their shape

- **Color and size similarity**

- **One-to-one mapping constraint**
  - Two parts at Time T should not correspond to one part at Time T+1
  - Global coherence: Correspondences all influence each other
Ternus Effect

Globally coherent correspondences (Long pause)

Locally determined correspondences (Short pause)
Globally Coherent Motion

Correspondences depend on distantly related correspondences

Automatic tendency to find globally consistent solutions
Illusory square moves, so the generation of illusory contours occurs before the generation of apparent motion.

If contours were generated only after motion is perceived, then people would see a pac-man (which requires no illusory contours) rotating.
Constraint Satisfaction Network for Apparent Motion Perception

Nodes
Represent correspondences between elements across frames
Activity represents strength of correspondence
Neural network does not learn
    Connections between units are hard-wired
Activation/inhibition spreads according to constraints:
    Shape, color, size, location similarity: if corresponding elements are similar, then activity increases
Motion similarity: Excitation between two nodes if similar directions of motion are implied by them

Consistency
    Consistent nodes excite one another
    Inconsistent nodes inhibit one another
    Consistent = one-to-one mapping
    Inconsistent = two-to-one mapping

Match
    Bias for each cell to have a correspondence
Processing in model
  Time = number of cycles of activation passing
  Soft-constraints (neural networks need not be tabula rasas)
  Activation passing leads to increased harmony over time
  Harmony = consistency between nodes

The necker cube is an ambiguous object

Each interpretation is internally consistent and harmonious
Networks settle into one of two consistent interpretations
Constraint Satisfaction Network for Necker Cube Perception

Inhibitory

Excitatory
Constraint Satisfaction Network for Necker Cube Perception

Unlikely
Constraint Satisfaction Network for Apparent Motion

Activity of a node is based on similarities between elements connected by the node.

Excitatory and inhibitory links are hard-wired according to constraints, not learned.

Inconsistent nodes if 2-to-1 mapping
Activity of \( B_{t+1} = \) Activity of \( B_t - \) Activity of \( C_t \)

Consistent nodes if not 2-to-1 mapping
Activity of \( B_{t+1} = \) Activity of \( B_t + \) Activity of \( C_t \)

The activity of other nodes

N objects per scene \( \rightarrow \) N*N nodes

Frame 1

Frame 2
Applications of the Apparent Motion Network

- **Similarity matters**
  - Similar objects are more likely to correspond to each other
- **Network finds consistent correspondences**
- **Hysteresis**
  - Once a stable percept is found, it resists change
  - Adding randomness helps appropriate restructuring
- **Predicts distribution of responses**
  - Make model stochastic by adding randomness to nodes
  - Even with randomness, stable percepts are found
- **Applicability to other areas**
  - Stereo depth perception (Marr & Poggio, 1979)
  - Analogical reasoning (Goldstone, 1994; Holyoak & Thagard, 1989)
The Correspondence Problem in Depth Perception

• Stereopsis as a major depth cue
  – Left and right eyes see different images
  – Differences in positions of objects in two eyes tells us about their depth
  – Correspondence problem: What element in the left eye corresponds to what element in the right eye?

• Analogy to apparent motion
  – Frame 1: Frame 2 :: Left eye image : Right eye image
  – For both apparent motion and stereopsis, for two images elements to correspond means that they come from the same real-world object
  – Constraints: location similarity, shape similarity, 1-to-1 mapping, smoothness
Random-dot stereograms (Julesz, 1971)
Retinal Disparities

Closer object = greater disparity between retinal images
Illusions in Stereopsis

The object that makes Image X (on the left eye) and Image B (on the right eye)

If a person sees X on the left eye, and A on the right eye and assumes that they come from the same object, this is where the object would need to be.

The closer two images are that are assumed to come from the same object, the closer that object is assumed to be.
FIG. 2.21. Two eyes viewing a simplified stereogram in which each eye sees just 4 dots. Each of the left eye's dots (L₁ to L₄) could match any of the right eye's dots (R₁ to R₄), so that the number of possible matches, shown with filled and open circles, is very large. The visual system chooses the matches which are shown with filled circles. (Adapted from Marr & Poggio, 1976, and reproduced from Bruce & Green, 1985, with permission.)
FIG. 2.26. A portion of a neural network to solve random-dot stereograms. (Reproduced from Frisby, 1979, with permission.)
The Mueller-Lyer Illusion

Cognitive Impenetrability