Lec 2: Using Space

Ecological Perception - A systems model that asks: How does human/world system accomplish perception?
- Assumes evolved perceptual systems enable perceivers to navigate through, and manipulate, their environments.
- Operation of systems generate "**Invariants**" = regularities that emerge whenever a human engages its visible space
- Since natural function is of primary concern, both theory & method aim to maximize "**Ecological Validity**" of research
  - The world is a cluttered, dynamic place & perceivers often move themselves, so this is what we should study

Founded by **J.J. Gibson**, who was commissioned to develop first simulator films for training pilots during WWII
- Research done in complex, real-world environments w/subjects solving real-world problems (navigate, manipulate).
- Identified "Invariants" in the relationship between an **active perceiver** and its **environment**
  - Note that most of what follows involves properties that emerge when a perceiver moves through space

PROBLEM: How does an observer get from here to there? How does it perceive its speed and direction of movement?
SOLUTION: Focus on destination point and move such that Optic Flow pattern radially expands from that point…

"**Optic Flow**" = when observer moves, environment streams to or from "Focus of Expansion" (FOE)
- Only FOE (subject's focal point in environment, towards which it is moving) is stationary
- Rest of visual environment expands as you move forward (i.e. as you approach FOE)
- Similarly, the visual environment contracts as you move backward (i.e. as you move from FOE)

As you move at a given **velocity**, to/from a given FOE, the **acceleration** of expansion/contraction is an "**Invariant**"
- i.e. Points closer to FOE will move more slowly, points farther from FOE move more quickly

Thus, focus on destination (FOE) & move so that Optic Flow symmetrically expands . . .
- 1) Works to get you there, AND
- 2) Enables you to perceive your relative distance from all points (based on their relative rates of expansion) AND
- 3) Enables you to perceive your own velocity (since expansion rates are a function of this)

PROBLEM: How do you keep from running into things? How do you catch or dodge something coming at you?
SOLUTION: Adjust trajectory (or reach/grasp) according to **Rate of Angular Expansion** ("Tau") of the object…

When an object moves directly at you, or you directly toward it, at a given velocity, its rate of change is an **Invariant**,
- i.e. Object expands at an accelerating rate at it approaches you, contracts at a decelerated rate as it moves away.

- Also **Invariant**: If object is moving directly to/from you, its expansion/contraction will be symmetrical
  - If it is *not* moving directly at you, there will be an asymmetry in its expansion/contraction
  - So, a moving object produces a kind of "local" (object-centered) Optic Flow pattern

PROBLEM: How do you determine the relative location (to you, to each other) of 2 objects as you (or they) move?
SOLUTION: Observe **invariant** patterns in "**Kinetic Occlusion**" (AKA "Accretion/Deletion")…
- Object that deletes (occludes) another is moving in front of it, OR is positioned between you and it as *you* move
- Object that shows accretion (becomes more and more visible as other moves) is revealed as behind other
- At a given velocity, objects closer together change in deletion/accretion more slowly than objects farther apart

PROBLEM: How determine the relative size and location of 2 objects when all you can move are your eyes?
SOLUTION: Observe relative frequency of the "**Texture Gradient**" on the substrate that they occlude (hide)…,

All substrates, natural or manmade, are perceived as a repeating pattern that increases in frequency as it recedes
- e.g. Manmade surfaces have regular patterns of bricks, cement squares, decorative tile, road lines, etc
- e.g. Natural surfaces have grass, rocks etc that appear farther apart when near observer, closer together when far

- **Invariant**: Gradients become higher in frequency as observer's focus moves farther away (lower freq as moves closer)
  - Frequency = # Cycles of texture per degree of Visual Arc (i.e. degrees of retina covered by stimuli)
  - e.g. If objects A and B are the same size, if object A obscures a higher frequency gradient than object B does, object A must be farther away than object B
  - e.g. If objects differ in size, at the same distance, the one that occludes more cycles is perceived as larger
  - Note: Typically, large/close objects LOOM = take up more of visual field, but above can take priority
- So, size and distance are **co-constraining factors** in this system (e.g. See *Emmert's Law* Sp=Sr X Dp)
  - And we can be fooled into seeing space that isn't there, misjudging size, etc. by artists who exploit invariants

Note that each of the above is a *partial* solution, often one of many that are operating

All of the above "Invariants" are examples of **emergent properties** of the perceptual system

In LAB 2, you will use many of the above **Invariants,** and will need to *discover* the **invariants** of **Motion Parallax**
HINT: "Motion Parallax" involves regularities in how (even stationary) objects move relative to one another, given the perceiver's position, movement, and focus

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Given how fundamental SPACE is in cognition, realize it or not, we often use Space to make cognitive tasks easier…

- **Spatial vs. Symbolic Processng**
  - e.g. Pilots shift from using #s to easier judging spatial distance from needle on dial to "Speed Bug"
    - See Speed Bug from Lec 1
  - e.g. Lave 1994: Asked to provide "3/4 of normal daily allowance of 2/3 cup of cottage cheese"
    - Cook first mumbles about having taken "calculus in college", but then measures 2/3 cup of c.c.
    - Plops on counter, rounds into a mound, cuts it into quarters, removes one - *Voila*!

- **Spatial Associations**
  - e.g. Use spatial simulation of a "Memory Palace" ("Method of Loci" - Greek philosophers 500 BC)
    – A mnemonic device: Easier to remember items associated with distinct locations
  - e.g. Chunking - Group subsets > fewer items to remember
    - e.g. CIAFBINCISDOD vs. CIA FBI NCIS DOD
  - e.g. Cache - Put things "in their place", esp with similar things, makes them easier to find when needed
    - e.g. Dishes, towels in different cupboards
  - e.g. Clean dishes in drying rack, dirty stacked on counter
    - Co-locate with associated structures involved in use

- **Task-Dependent Organization**
  - ACCESS - Placing things WHERE they will be used
    - e.g. Cook brings all ingredients and tools to Work- Space (i.e. within reach) - AKA **"Praxic Space"**
      - Allows easy, efficient access, in sometimes time-sensitive procedures
    - e.g. Store keys near door, since need when leaving
    - e.g. Turn handles of cooking pots toward (cooler) edges of stove, so won't get too hot to handle
    - e.g. Production line w/bins of parts
      - Note tradeoff during assembly - can lay out in order ***or*** for placement, but not both…

  - ORDER - Arrange access based on ORDER elements will be used
    - e.g. Put objects **in a line**, in the **order** they are needed - often seen in assembly lines
      - Next is easiest to reach, and looms in visual field as approach
    - e.g. Bagger separates items by size, weight, fragility to organize effective bagging
    - e.g. **Hierarchical sorting** allows search to be limited to one level at a time, directed to relevant details

  - MARKING - Use proximity in space to mark - or "**highlight**" - as relevant, exceptional
    - e.g. Once measure & cut butter, lay knife on cut section to ID, later, which was measured part
    - e.g. A set table (arranged for eating a meal) marked as not available for other functions (doing homework)
    - e.g. Workers lay rag across hot handles: *Beware!*
    - e.g. Pill bottle on keyboard - unusual placement (esp in commonly engaged location), increases **salience**
      - "Salient" = attention-grabbing, increased likelihood of noticing

See Recommended Reading: Kirsh, D. (1995) The intelligent use of space. *Artificial Intelligence, 73:*31-68.