Consciousness and Groundedness

15-494 Cognitive Robotics
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What is Consciousness?

- A philosophical swamp!
- Phenomenology: what is the sensation “red” ?
  - Qualia: sensations, like “red” or “sweet smelling”.
  - “The way things seem to us”
- What is it “like” to have mental states, e.g., to see a sunset as “red” ?
  - Explanation in terms of retinal receptors is insufficient.
  - Nagel: “What is it like to be a bat?” (echo-location)
- The Mind/Body Problem: how can physical matter (the brain) give rise to mental states?

Dualism

- Descartes: mind (spirit) is separate from body.
- Politically expedient: allowed study of the body (including perception and action) without threatening religious leaders concerned with spirit.

Materialism

- The doctrine that mind is *just* a phenomenon of the body, i.e., mental states = neural states.
- Is it really just that mechanical? Some people hope not.
- Quantum theories of consciousness: the next best thing to dualism. Alas, no evidence.

Aspects of Consciousness

- Awake
  - Altered states of consciousness: sleep, dreaming, trance, ...
- Self-aware
  - All great apes except gorillas pass the mirror test.
- Self-knowledge
  - Able to describe one's own beliefs and motivations.
- Introspection
  - Ability to examine one's own mental states or “thoughts”.
  - Not infallible, but still useful.
- Internal monologue?
  - Having a mental language? (What about animals?)

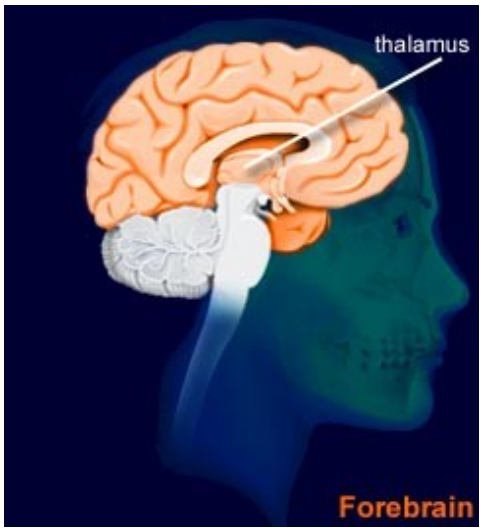
Phenomenological vs. Access Consciousness

- Phenomenological consciousness: sensing the environment.
- Access consciousness: having a “thought” about something. The thought can then be referred to in other thoughts.
- P-consciousness without A-consciousness: hearing a sound but paying no attention to it.
- A-consciousness requires thought; P-consciousness does not. (Are animals only P-conscious?)

“Higher Order Thought” Theory of Consciousness

- Consciousness as a property of mental states means consciousness *of* mental states.
- Consciousness is the ability to have thoughts about your thoughts.
- But what if some mental states can be experienced but aren't describable by “thoughts”?
- What qualifies as a “thought”?

Neurophysiological Correlates of Consciousness



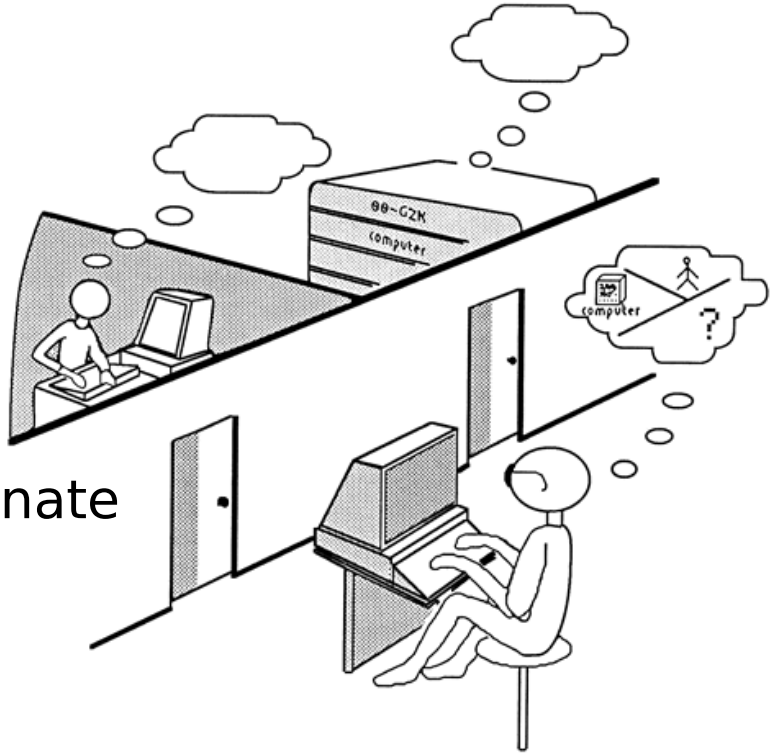
- Is consciousness localized in the brain?
  - May be distributed throughout.
  - Lesions to intralaminar nuclei of the thalamus cause loss of consciousness.
    ILN projects widely to cortex.
- How do anesthetics induce unconsciousness?
  - Decoupling of cortical areas.
  - Reduction in cortical activity.
- Are there “consciousness neurons” in the brain?
  - If yes, where are they?
  - If no, then does every neuron contribute to consciousness?

Unconscious Cognition

- Blindsight
- Tachistotscopic experiments
- Priming effects, e.g., “dealer” $\rightarrow$ (“deck”= card deck)
- Dorsal visual pathway (“where” stream) may be purely perceptual; ventral (“what”) stream involves cognition.
- Learned fear reaction (amygdala)

Can Robots Be Conscious?

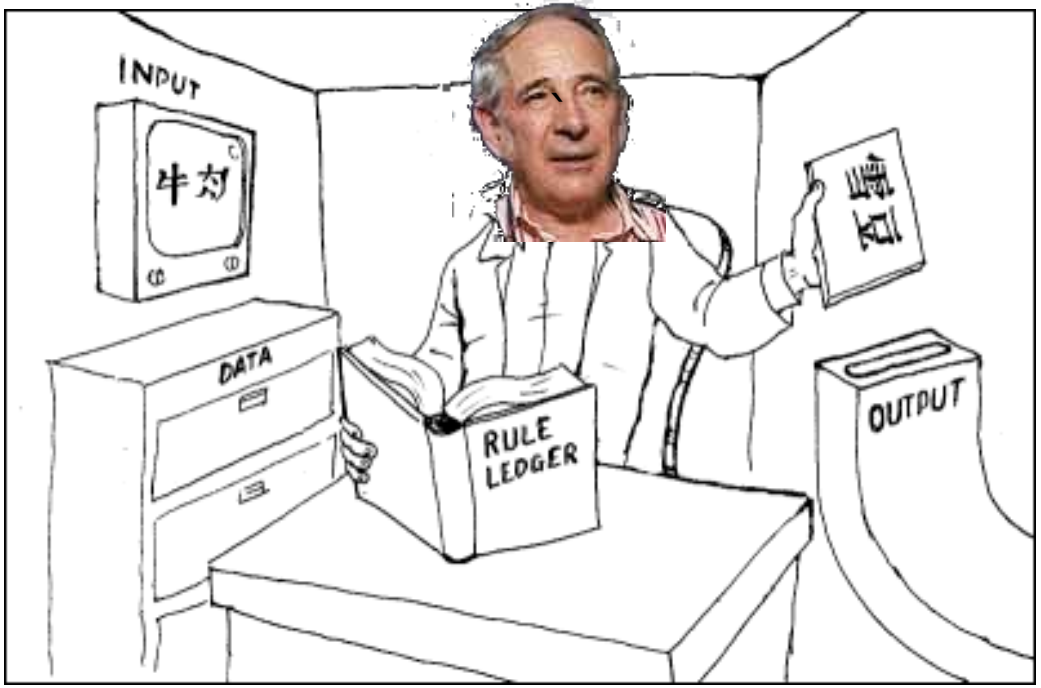
- Similar to another famous question:
  - Could a computer ever “think” ?
- Turing test (the imitation game).
  - Can a human observer reliably discriminate a person from a machine, based on a written conversation?



- Weak vs. strong AI:
  - Weak AI: develop algorithms that allow computers to perform tasks currently considered to require “intelligence”.
  - Strong AI: get computers to *be* intelligent.

Searle's Chinese Room

- Searle doesn't understand a word of Chinese.
- Does the “Searle + room system” understand Chinese?



http://www.unc.edu/~prinz/pictures/c-room.gif

- Could the room be “conscious”?

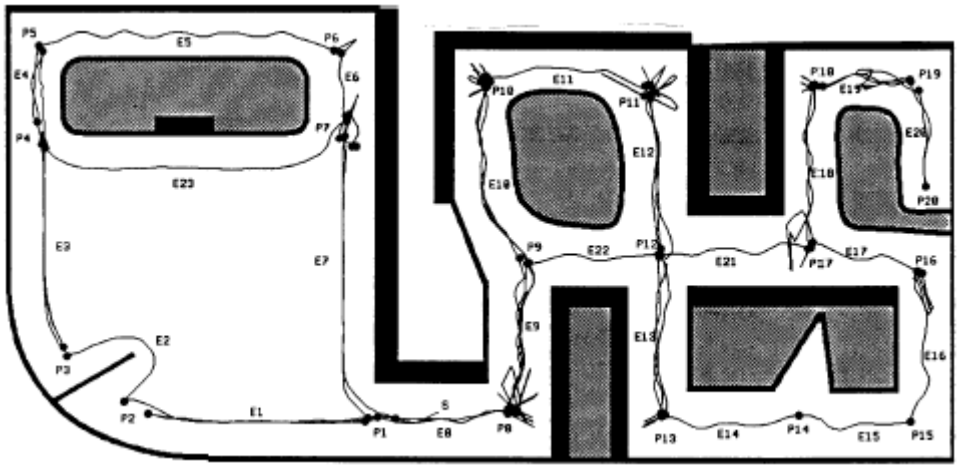
Groundedness

- Percepts aren't arbitrary signals.
- They are about something: the relationship of the perceiver (body and brain) to the world.
- They are causally connected to the world.
- Symbols in the Chinese room are not grounded.
- Some say computers cannot “think” because their symbols are not grounded.
- Is groundedness important for consciousness?

Groundedness (cont.)

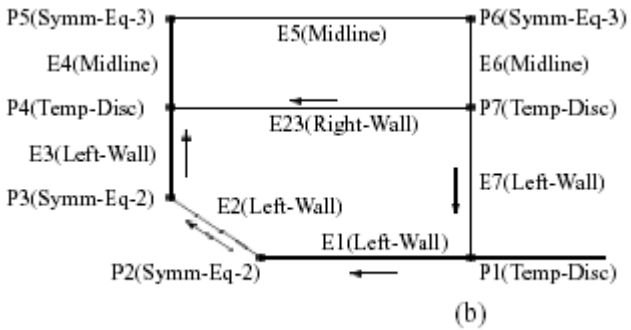
- Computers programmed to “notice” certain sensory signals might as well be performing arbitrary operations.
- But can robots, situated in bodies, acquire a repertoire of encodings that reflect their interactions with the world, and are thus grounded in experience?
- Kuipers: to discover abstractions for sensorimotor interactions, need to detect invariants.
- Example: if you turn a full 360º, the world looks the same afterwards.

Spatial Semantic Hierarchy

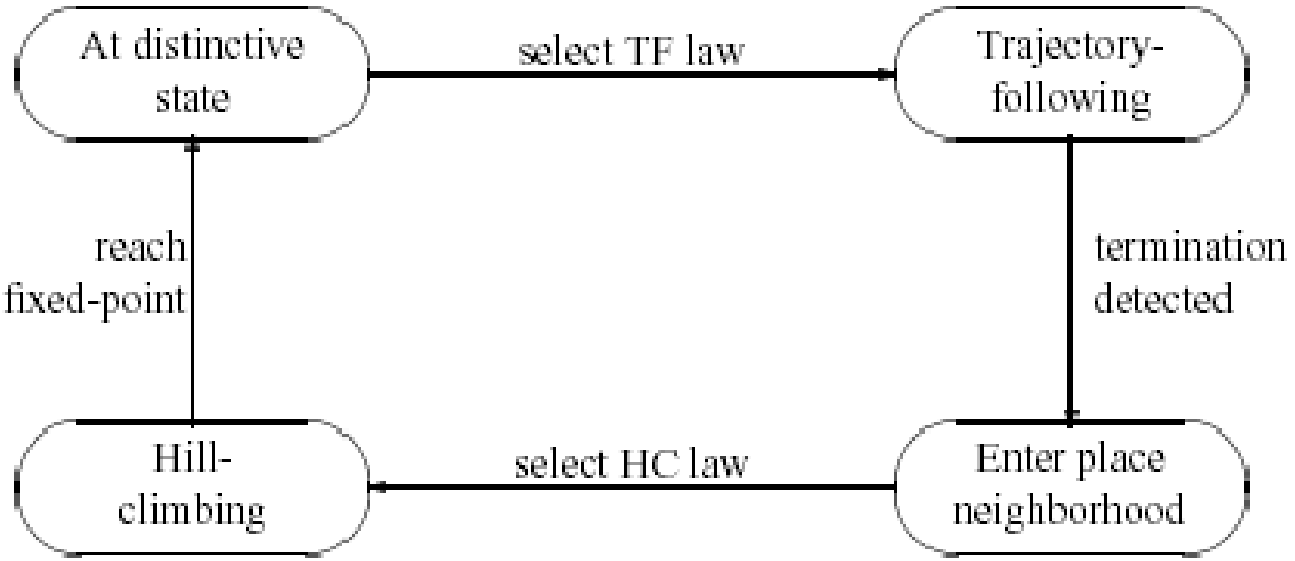


From Kuipers (2000)

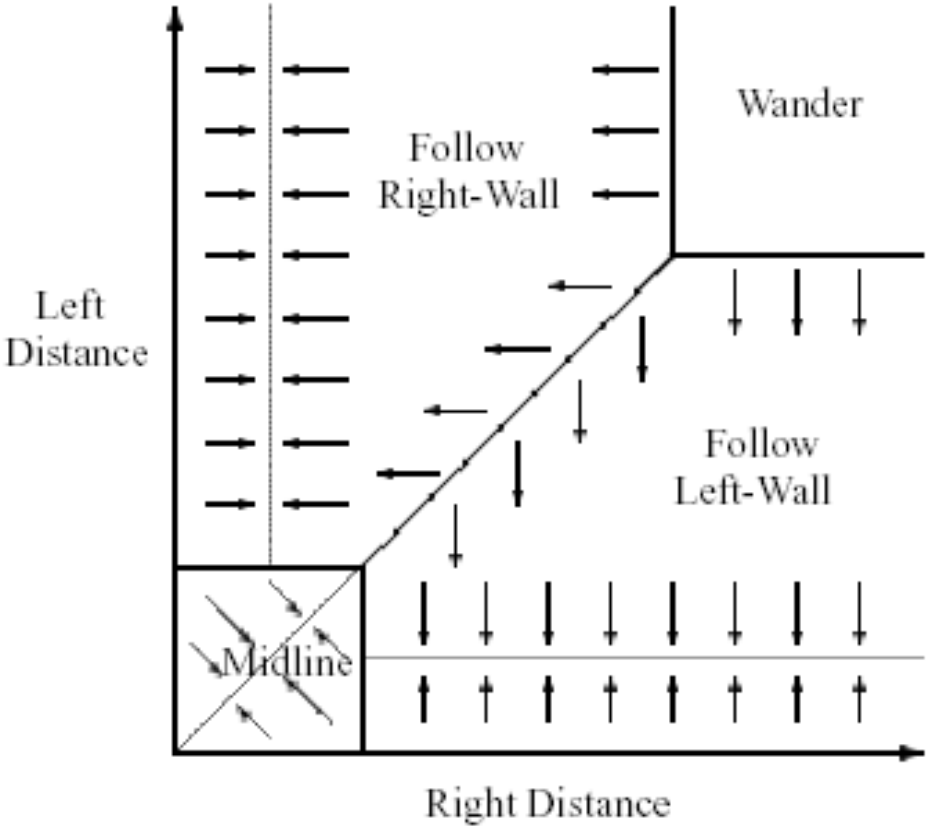
- Find distinctive places in the world, that can be reached by hill-climbing. Examples: corners, branch points.
- Find control laws that connect distinctive places, e.g., by wall-following.
- Construct topological graph reflecting this.



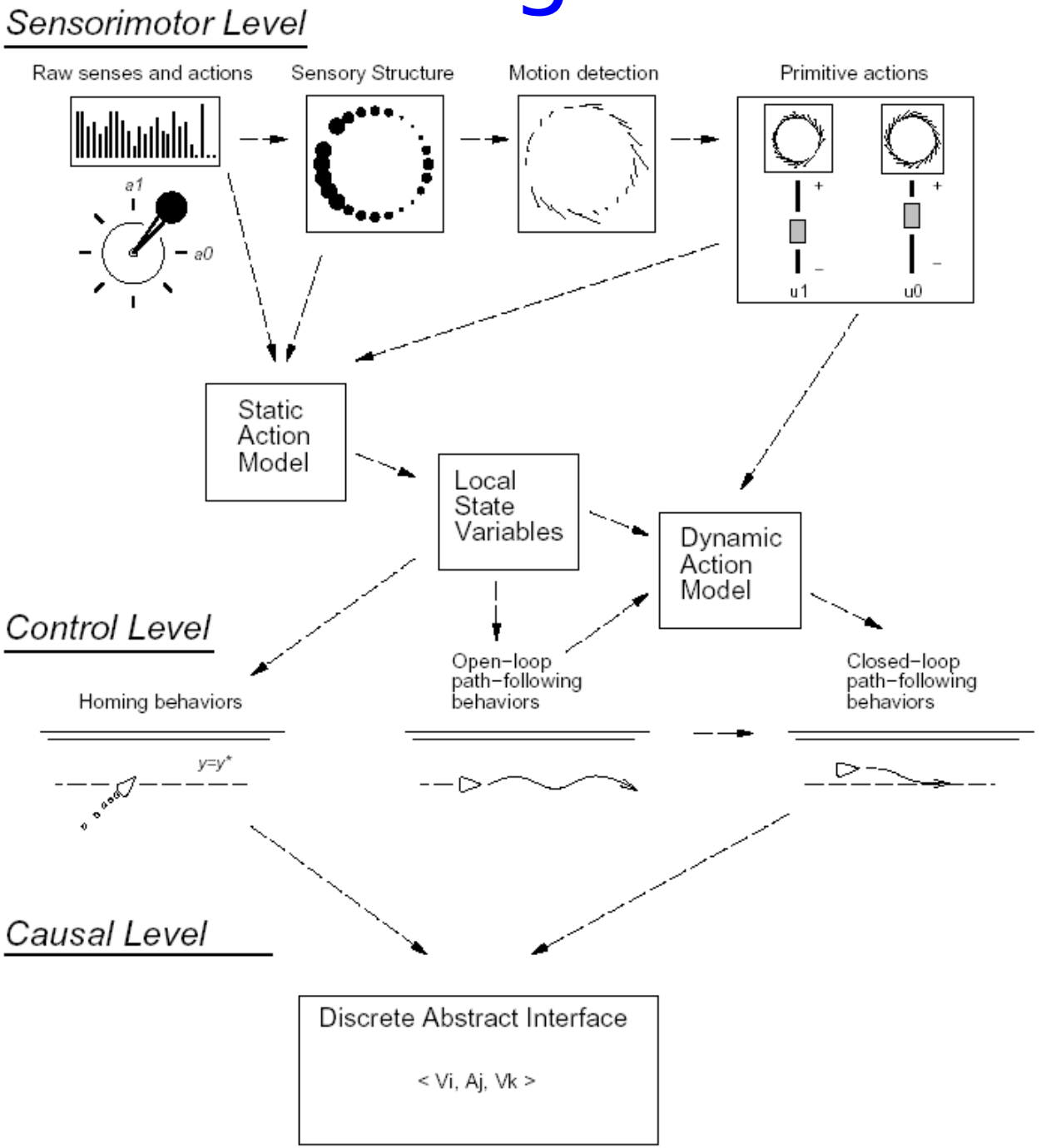
Selecting Control Laws



Trajectory-Following Laws

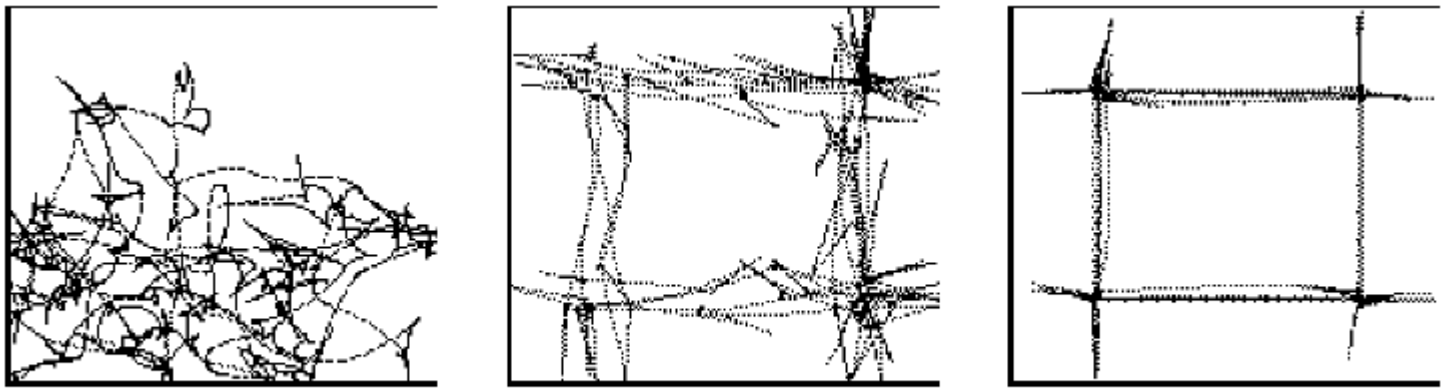


Learning Actions



Exploring A Simple World

- (a) random wandering
- (b) open-loop homing and path following: use actions that change one feature while keeping another relatively constant
- (c) closed-loop control laws can actively reduce deviations in the constant feature



Kuipers' “Trackers” Proposal Concerning Consciousness

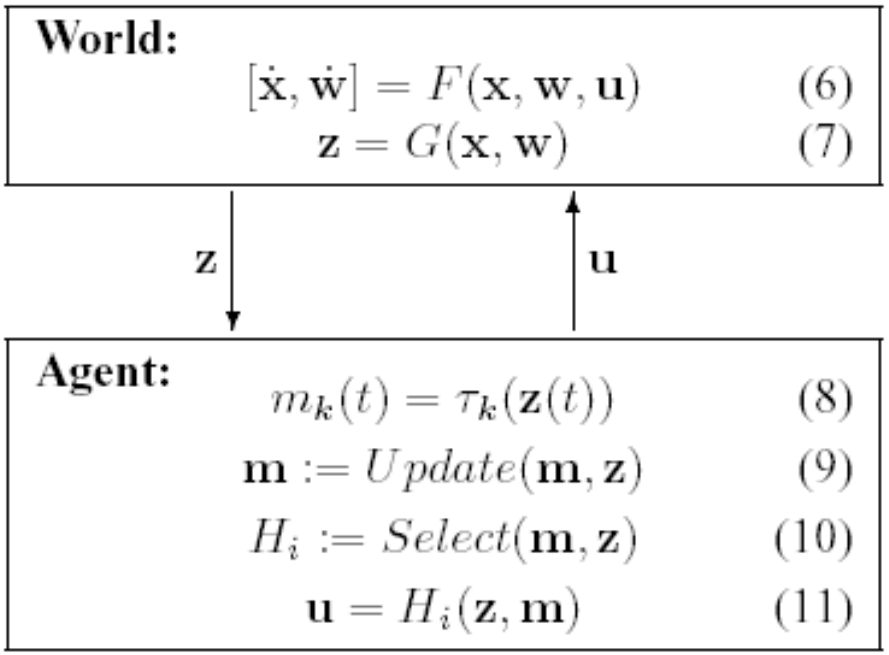
- Focuses on phenomenological consciousness.
- Says nothing about access consciousness.

Basic Idea:

- We experience the world as a rich high bandwidth stream of sensory impressions.
- A “tracker” monitors some feature of the environment over time. Allows us to be “aware” of the feature.
- Conscious experience is derived from trackers.
- Attention works by controlling trackers.

Kuipers' Trackers

- **x**(t) = body state
- **w**(t) = world state
- **z**(t) = sensor stream
- **u**(t) = motor stream
- **m**(t) = internal symbolic state
- m_k(t) = state of tracker τ_k



- F(**x**,**w**,**u**) = how the world and body are updated
- G(**x**,**w**) = how the world and body are sensed
- H_i(**z**,**m**) = i^{th} *control* law

Trackers and Searle's 11 Features of Consciousness

1. Qualitativeness

> Every conscious state has a qualitative feel to it... [This includes] conscious states such as feeling a pain or tasting ice cream... [and also] thinking two plus two equals four." (Searle 2004)

- "The vividness, intensity, and immediacy of subjective experience are due to the enormous information content of the sensor stream **z**(t)." (Kuipers 2005)

- Trackers provide structure, and rapid access to parts of the sensory stream.
  - Remembering "red" (rough symbolic label) vs. seeing a particular shade of red in a sunset.

Searle's Features (cont.)

2. Subjectivity:

- "Because of the qualitative character of consciousness, conscious states exist only when they are experienced by a human or animal subject." (Searle 2004)

- Consciousness is experienced exclusively from a first-person point of view.
- What this means: agent has privileged access to the sensor and motor streams of its own body, **z**(t) and **u**(t).
- The body is physically embedded in the world, so these streams have causal connections to the world.
- But couldn't a robot have a "point of view"?

Searle's Features (cont.)

3. Unity

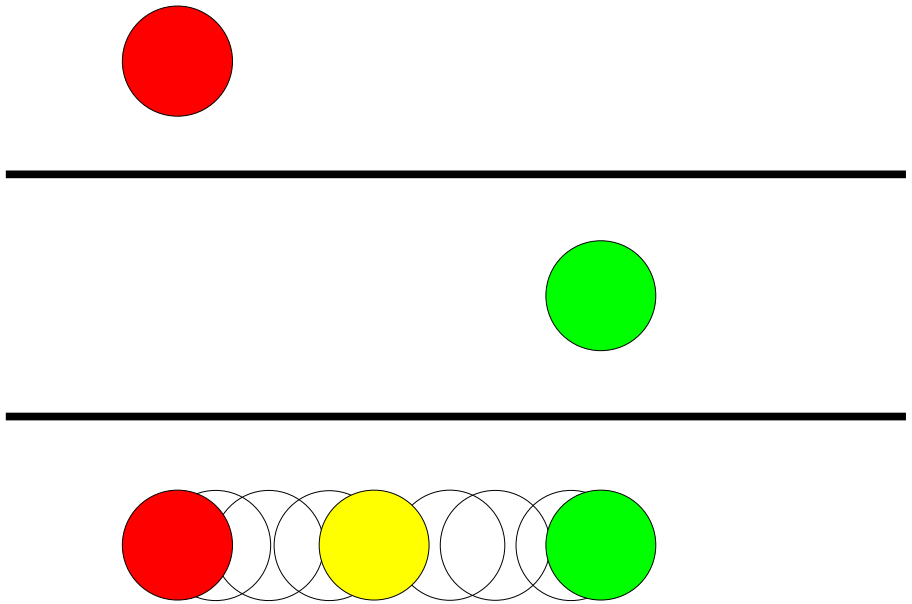
- We experience the audio-visual surround as a single unified field, continuous in space and time.
- Our actual sensory stream is not so unified.
  - Visual acuity is low outside of the fovea.
  - Multiple saccades are necessary to “see” a scene.
- Dennet's “multiple drafts” model of consciousness: unity and sequentiality are carefully maintained illusions.

“Cartesian Theater” vs. Multiple Drafts Theory

- Daniel Dennett describes conventional theories of conscious experience as being like a “Cartesian theater”:
  - Events play out in strict sequence and are perceived by an inner observer.
  - But who is looking at the play?
- Some psychophysical experiments indicate that sequentiality is *not* always maintained,
  - Color phi effect
  - Flash ring effect
- The mind doesn't “observe” reality, it *constructs* it.

Color Phi Effect

- “Moving” dot appears to change color in mid-flight:

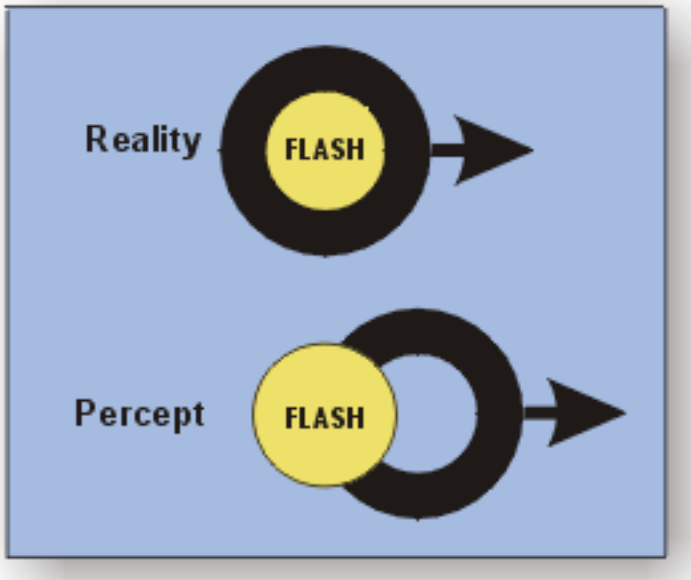


- How does the brain know at time t=75 ms that the dot will change color at time t=150 ms?

Flash Lag Effect

- A flash at the center of a moving ring is perceived to occur offset from the ring.

- Motion channel faster than intensity channel?



- Online demo: www.michaelbach.de/ot/mot_flashlag1

Searle's Features (cont.)

4. Intenionality

- Ability to refer to actual objects “in the world”.
- Kuipers: Trackers bind the sensor stream to a symbolic description of “the world”.

5. Distinction Between Center and Periphery

- Ability to mentally direct one's focus of attention.

6. Situatedness

- Knowing where you are, the time, one's situation, etc.

7. Active and Passive Consciousness

- Perceiving sensations of the world (passive) vs. perceiving oneself acting in the world (active).

Searle's Features (cont.)

8. Gestalt Structure

- We perceive things as coherent wholes, not isolated features or fragments.
- Kuipers: Trackers could track these percepts.

9. Mood

- One's mood lends a “flavor” or “tone” to consciousness.

10. Pleasure/Unpleasure

- For any conscious state there is some degree of pleasure or unpleasure.

11. Sense of Self

- In normal conscious experience one has a since of onself; “a sense of myself as a self”

Implications for Tekkotsu

- The notion of “tracking” would seem to be useful for maintaining continuity of attention across actions.
- Visual target tracking (with the Lookout) is in some ways analogous to Kuipers' tracker notion.
- What's missing?
  - Sensory memory storing recent perceptions (500 msec?) How do we know when things have changed?
  - Thoughts about percepts (access consciousness)
  - Internal language.
  - Goals, plans, etc., etc., etc.