Challenges for Logic AI Systems

Northwestern EECS 348

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Logic as a Foundation for AI

- Logic: extremely expressive, powerful
  - Theorem provers: useful in practice
- But:
  - Writing down needed knowledge is hard
    - So-called Frame, qualification, ramification problems
    - => Knowledge acquisition bottleneck
  - Logic systems are “incomplete”
  - Logic systems are brittle

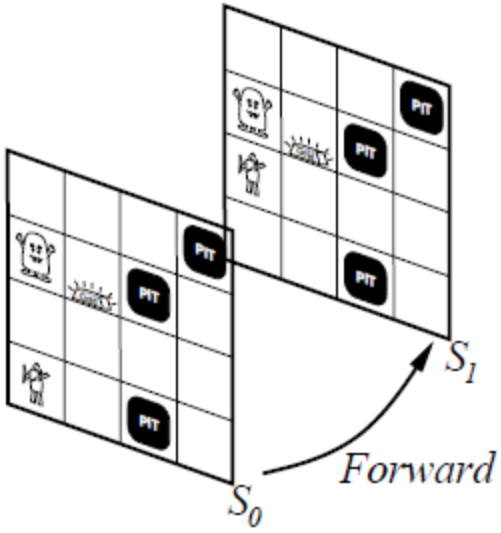
The real world: Sensing and Acting

- Perception
  - three binary inputs [smell, breeze, glitter] at each time *t*
  - $\forall s, b, t$ Percept([*s, b,* Glitter] , *t*] => AtGold(*t*)

- $\forall t$ AtGold(*t*) => Action(Grab, *t*) ?
  - Infinite Loop!
- $\forall t$ AtGold(*t*) $\wedge \neg$**Holding(Gold, *t*)** =>
  Action(Grab, *t*)

Keeping track of Change

- Facts hold in particular situations
  - E.g., Holding(Gold, *t*) may be False, Holding(Gold, *t+8*) true
- Agent must keep track of change



Frame Problem

- Effect axioms
  - $\forall t$ Standing((i, j), t) $\wedge$ Facing(Up, t) $\wedge$ Action(Forward, t)

    => Standing((i,j+1), t + 1)

- But…HaveArrow(t + 1) ?
- "Frame" axioms keep track of what *doesn't* change
  - Action(Forward, t) => (HaveArrow(t) $\wedge$ HaveArrow(t + 1))
  - Etc. etc. etc.

Representational Frame Problem

- Historically thought to be extremely tricky
- Can be solved by writing axioms about fluents rather than actions

Holding(Gold, t)

<=>

¬ Holding(Gold, t-1) and action at t-1 made it true

or

Holding(Gold, t-1) and no action at t-1 made it false

Qualification Problem

- Action's preconditions can be complex

- Action(Grab, t) => Holding(t)

  ….unless gold is slippery or nailed down or too heavy or our hands are full or…

Ramification Problem

- Actions can have many consequences
  - $\forall t$ Standing((i, j), t) $\wedge$ Facing(Up, t) $\wedge$ Action(Forward, t)

    => Standing((i,j+1), t + 1)
  - But also

    => In(Basketball, (i, j+1), t + 1)

    if I'm holding a basketball
  - Writing all these down -- difficult

Knowledge Acquisition

- Remember the Colonel West story
  - We converted text to logic
  - In practice…who does this?

- Qualification, Ramification problems tell us we need *tons* of “common-sense” knowledge

- The infamous “knowledge acquisition bottleneck”

Knowledge Acquisition: Options

- Type it all in yourself
  - Cyc
- Get Web citizens to type it all in
  - Open Mind
- Extract it from the Web
  - KnowItAll, TextRunner

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Gödel's Incompleteness Theorem

- Completeness Theorem: All valid statements have proofs in FOL

- Incompleteness Theorem: For any FOL KB enhanced to allow mathematical induction, there are true statements that *can't* be proved.

Gödel's Theorem: Sketch (1)

- Idea:

  This statement is false.

- More specifically:

  This statement has no proof.

Gödel's Theorem: Sketch (2)

- Assign numbers to sentences, proofs
  - E.g. by sorting by length, then alphabetically
- Consider the sentence $\alpha(j, A)$
  - For all numbers *i,* statement #*i* is not a proof for statement #*j* from the axioms *A*
- Let σ be the sentence $\alpha(\#\sigma, A)$
  - σ false? But it has a proof!
  - σ true? It's unprovable!

Gödel's Theorem: Ramifications

- Argument: Computers are limited by Gödel's theorem, whereas humans aren’t.

- Thus, AI is doomed

Three counter-arguments

- Gödel's theorem applies to math induction systems, e.g. Turing Machines
  - Computers aren't *really* Turing machines
- "Steve cannot say this sentence is true."
  - But Steve might be able to do other cool stuff
- Are humans really immune to the theorem?

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Brittleness of Logic Systems

- Consider a KB with just one contradiction
- That KB entails everything
- This is a problem because much of the world is uncertain
  - Perception, action, incomplete information, controversies, etc.

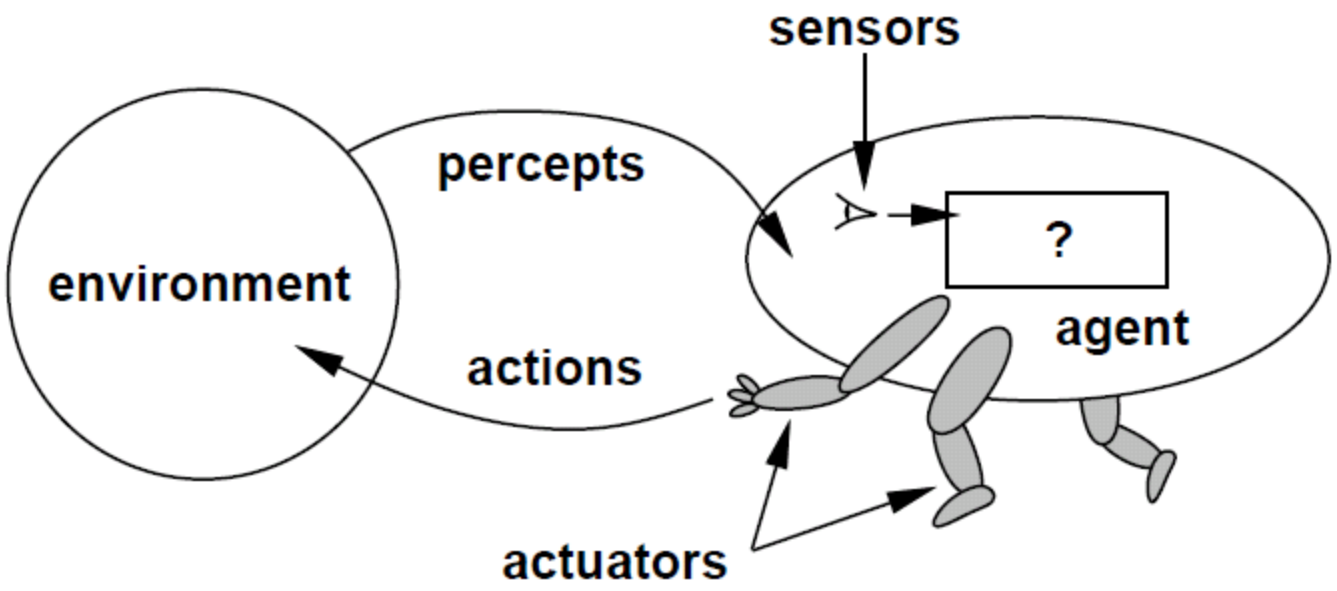
Toward “Modern” AI

- Limitations:
  - Knowledge Acquisition Bottleneck, Brittleness
- “Modern” directions:
  - Situatedness, embodiment
  - Probability
  - Learning from data

Alternatives: Focus on Behavior

- Argument: we can't even build systems that do what ants do
- In the timeline of evolution, simple cells->ants took much longer than ants->humans
- Let's start by building ants
  - Environment, body can make tasks **easier**
  - Incrementally solve **real** problems end-to-end

Intelligent Agents



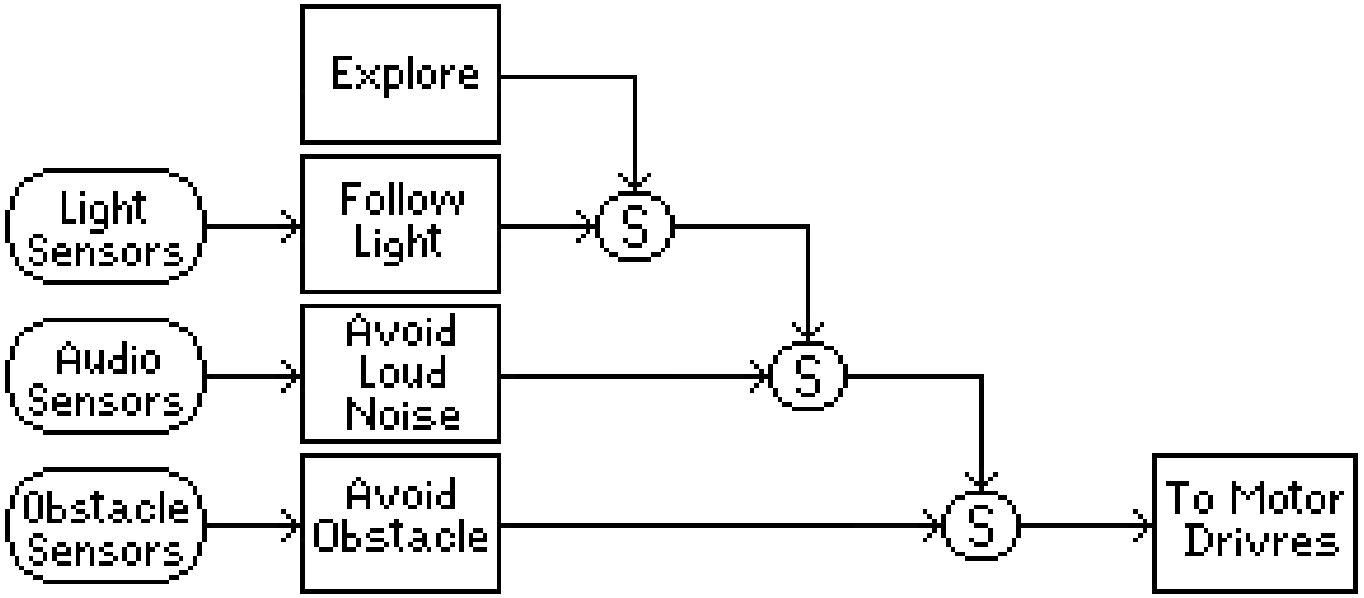
- Sensory/motor aspect
  - more **important**, more **coupled**, more **integrated** with rest of intelligence than originally thought

Behavior-based robots as a foundation for AI

- Common-sense knowledge arises from our interaction in the world
- Thus, the road to AI is paved with real-world interaction
  - We must build robots
- Another possibility: softbots

Subsumption Architecture

- Behavior-based robotics



Beam-wiki.org

Other “modern” trends

- Biological inspiration, e.g.:
  - Neural networks
  - Hexapod robots drawing on insect nervous systems followed subsumption architecture
- Probability theory
  - Handles uncertainty, overcomes brittleness
- Data

Learning from Data

- Quantities of data are exploding -- let's learn from it

- "Machine learning"