What Is A Knowledge Representation?

6.871 - Lecture 10

Outline

- What Is A Representation?
  - Five Roles
- What Should A Representation Be?
- What Consequences Does This View Have For Research And Practice?
  - One answer to a foundational question
  - The "spirit" of a representation
    - » The spirit should be *indulged*
      - In analysis
      - In system construction
  - The central task of knowledge representation

Terminology and Perspective

- Inference = getting new expressions from old
  Not limited to deductive (sound) inference.
- "Knowledge Representation Technologies":
  rules, frames, logic, semantic nets, etc.

What Is a KR?

1) It's a surrogate.
   A substitute for the thing itself.
2) It's a set of ontological commitments.
   In what terms should I think about the world?
3) It's a fragment of a theory of intelligent reasoning.
   - What is intelligence?
   - What can I infer from what I know?
     (i.e., which inferences are sanctioned?)
   - What should I infer from what I know?
     (i.e., which inferences are recommended?)

What Is a KR?

4) It's a medium for pragmatically efficient computation.
   The computational medium in which thinking is accomplished.
   How should I organize information to facilitate that thinking?
5) It's a medium of expression and communication.
   A language we use to talk to the machine.

[1] It's A Surrogate

- A stand-in for the object in the real world.
- Operations on the KR substitute for actions in the world.
- Reasoning is itself a substitute for action.
- (Conversely, actions can substitute for reasoning).

[1] It's A Surrogate

- Questions:
  - A surrogate for what? → semantics
  - How accurate a surrogate? → fidelity
    - » More fidelity is not automatically better
    - » Perfect fidelity is impossible.

[1] It's A Surrogate

Perfect fidelity is impossible

→ We inevitably lie.

→ Incorrect inferences are inevitable.

Sound reasoning can't save us.

A better representation can't save us.

→ We have already sinned.

→ We may as well be pragmatic about it.

[2] Set of Ontological Commitments

- Surrogates are inevitably imperfect
  → KR selection unavoidably makes an OC.
- Commitment occurs even at the level of the KRT's
  - Diagnosis as rules vs. frames.

[2] Set of Ontological Commitments

- The commitment accumulates in layers
  - EG: medical diagnosis
    - » frames → prototypes, defaults, taxonomy
    - » prototypes of what?
    - » what diseases?
- Commitment is inevitable
- Commitment is crucial

[3] Fragment of a Theory of Intelligent Reasoning

- What are all the inferences am I permitted to make?
  - Example: classical formal logic; sound inference
  - Other answers
    - » Logic: circumscription
    - » Rules: plausible inference
    - » Frames: good matches, expectations, defaults.

[3] Fragment of a Theory of Intelligent Reasoning

- What are all the inferences am I permitted to make?
  - Logic: sound inference
- Which inferences am I encouraged to make?
  - Example: Frames
    - » What reasoning to do: anticipatory matching
  - Other examples
    - » SN: propagation; links.
    - » Rules: chaining; associations.
    - » Logic: lemmas; connection graphs.
  - Combinatorial explosions
    → the need for guidance on what we *should* do, not only what we *can* do.

[4] Medium for pragmatically efficient computation

- Reasoning with KR means computing with it.
- The pendulum swing
  - Heuristic adequacy (1969)
  - The logicist view (circa 1974)
  - The computational imperative view (circa 1984)

[4] Medium for pragmatically efficient computation

- The pragmatics of it: How can I organize information to facilitate reasoning?
  - Example:
    Frames — triggers, procedural attachment, taxonomic hierarchies

[5] Medium of Expression and Communication

- It's how we say things about the world.
- It's how we communicate with the reasoner.
- In principle, as a medium of expression:
  - How general, how precise?
  - Does it provide expressive adequacy?
- In practice, as a medium of communication:
  - How transparent is it?
    Can we understand what's been said?
    Can we generate the right expression?

What *Should* A Representation Be?

1) Surrogate: imperfect fidelity
   → incorrect inference is inevitable
   → take a pragmatic view of soundness/efficiency

2) Ontological commitment
   Unavoidable
   One of the most important things a KR can supply
   A source of power
   Insufficiently explored
   Important at the tool level

What *Should* A Representation Be?

3) Theory of intelligent reasoning
   Representations should inform the reasoner about what inferences should be encouraged

What *Should* A Representation Be?

4) Medium of pragmatically efficient computation
   - In real use: average time complexity matters.
   - Doing well most of the time on problems actually encountered
   - In real use: worst cases need not be fatal.
   - Coroutine-style resource-limited comp'n is interruptible
     → freedom from requiring guarantees
   - Representation should inform the reasoner about how to organize information to make the encouraged inferences inexpensive, on average.
     → data structures
     Ex: a-k-o assertions vs a-k-o links

What *Should* A Representation Be?

5. Medium of expression and communication
   - "Possible" vs. reasonably obvious and natural.

What *Should* A Representation Be?

- All five roles matter.
- The five roles characterize the "spirit" of a representation.
- The spirit should be indulged, not overcome.
  - "Programming the representation"
  - If it doesn't fit naturally, design a new one.

What *Should* A Representation Be?

Every representation is only one of several possible approximations to reality.

→ there is no one right one

→ one or another may be better suited to a specific task

→ need to connect representation to the reasoning to the task

→ Let the domain tell you:

a good set of abstractions (ontology)
which inferences are needed/recommended

→ Build those abstractions into the language

→ Make the recommended inferences easy

What *Should* A Representation Be?

- There's significant power in attending to the domain.
- Domain independent languages are overlooking an important source of power.

Summary

- What Is A Representation
  1. It's a surrogate, one of several approximations.
  2. It's a set of ontological commitments.
  3. It's a fragment of a theory of intelligent reasoning.
  4. It's a medium for pragmatically efficient computation.
  5. It's a medium of expression and communication.

Summary

- What Should A Representation Be?
  - Pragmatic in its view soundness and efficiency.
  - Strong in ontological commitment.
  - Pluralistic in defining sanctioned inferences.
  - Effective in recommending inferences and organizing information.
  - Efficient in the average case (pragmatic efficiency)
  - Effective as a medium of communication.
  - Supported by guarantees but not limited by them.
  - Focused on the world.
  - Rich in abstractions matched to the task.
  - Indulged.

Summary

- Fundamental task of KR:
  Capturing the richness of the natural world.