The Interaction of Representation and Reasoning

University of St Andrews
27th November 2013

Alan Bundy

School of Informatics
University of Edinburgh
Agents must have World Models

- **Internal model needed:**
  - To predict the effects of actions during planning.
    - Including models of other agents.
  - Called *logical theories*.

- **World infinitely rich.**
  - Any model is an approximation.
  - Must find sweet spot,
    - trading expressivity against efficiency.

- **Each agent will have an theory tuned to its role.**
  - Appropriate representation is the key to effective problem solving, e.g., reduce search.

- **However, agents must communicate.**
  - So theories must be aligned.
Representation as the Key 1

John McCarthy’s Mutilated Checkerboard: Can we tile board with dominoes?

Colouring of domino removes search from solution.
Representation as the Key 2

- Saul Amarel study of missionaries and cannibals.
- How change of representation affects search space size.
- Successive representations significantly reduce search.
Representation as the Key 3

Andy deSessa’s

**Bouncing Ball**: Where does energy go at moment of impact?

Essential to idealise ball as having extent.
Representation Formation

- Representation must be tuned to goal and environment.
- Design representation to suit problem.
- Abstract relevant information from sensory input: **idealisation**.
- Decide what is negligible and can be ignored.
Formation of Representations 1

- **Mecho Project**: solve mechanics problems stated in English.
  - Project with George Luger, Martha Palmer, Bob Welham, Chris Mellish, Rob Milne.

- Real world objects idealised automatically.
  - particles, inextensible strings, light pulleys.

- **Idealisation fossilized**:
  - inferred from problem type.
Idealisation

- Particle on plane
- Container in fluid
- How to idealise this ship?
- Relative Velocity Problem
- Archimedes Principle Problem
Formation of Representations 2

- **Eco project:** assist users to construct ecological model.
  - Project with Bob Muetzelfeldt, Mike Uschold, Dave Robertson.
- **Heuristics for suggesting idealisations.**
- **Representation formation as interaction between human and machine.**
Representations must Evolve.

- Representations must evolve:
  - as world changes;
  - as problems change;
  - to communicate with other agents.

- Most representations built by designer and static.

- Representation evolution must be dynamic and automated:
  - Consider emergency response;
  - Multiple agencies – must inter-operate.
Triggers for Representational Change

- Can prove false conjectures.
- Fail to prove true conjectures.
- Reasoning inefficient.

Analysis of failure can suggest appropriate repair.
Repair can be to language as well as beliefs.
Representation Change 1: Coin-in-the-slot

- Parking meter requires £5.
- Must be in coins.
- Not including new 50p.
- Or bent or underweight coins.
- But some foreign coins will work.
Representation Change 2: Motherhood

- **Motherhood**: Mother(person)
  - MaternalGrandMother(p) = Mother(Mother(p))

- **Types**: natural, step, adopted, foster, surrogate, egg donor, ....
  - Mother must be predicate, not function.

- **Split Relations**: StepMother(mum,child)

- **Add Argument**: Mother(mum,child,kind)
  - Mother(gm,m,k₁) & Mother(m,gc,k₂) → MaternalGrandMother(gm,gc,Combine(k₁,k₂))
Latent heat: change of heat content without change of temperature.
- Black discovered in 1761.

Before Black, heat and temperature conflated.

Separation of conflated concepts necessary precursor to discovery.

Conflation of “morning star” and “evening star” into “Venus” in reverse direction.
Representation Change for Agents

- **ORS**: repairs faulty theories by analysing failed multi-agent plans.
  - PhD project of Fiona McNeill.
- Changes include abstraction and refinement of language,
  - e.g., adding arguments, changing predicates.
- Allows agents with slightly different theories to communicate.
- Technology essential for Semantic Web
Example: Hotel Bill

- Planning agent (PA) forms plan, but it fails.
- Failing action: \textit{Pay(PA, Hotel, £200)}. Hotel agent refuses to accept money.
- Surprising question precedes failure. \textit{Money(PA, £200, Credit\textunderscore Card)} – Where \textit{PA} expected \textit{Money(PA, £200)}
- Change binary \textit{Money} to ternary.
Representation Evolution in Physics

- **GALILEO**: evolves physical theories.
  - Project with Michael Chan & Jos Lehmann.
- Experimental evidence may contradict known theory.
- Using *theory repair plans* to capture common patterns.
  - Where’s my stuff?
  - Inconstancy.
  - Unite.
- Case studies include: dark matter, latent heat, Boyle’s Law, etc.
Example: Dark Matter

- Mismatch between prediction and observation:
  - orbital velocities of stars in spiral galaxies.
- Split galaxy into:
  - visible stars;
  - invisible dark matter;
  - and their total.
- Alternative solution via MOND:
  - gravity depends on relative acceleration.
Conclusion

- Formation of representation must be under machine control.
  - To deal with multiple agents, changing world.
- Representational change triggered, for instance, by reasoning failures.
  - Language changes as well as belief revision.
- Major challenge for next half century.