PS452

Intelligent Behaviour

Lecture 4: Artificial Intelligence Landmarks

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Part 2: Intelligent Behaviour in Machines

- **Lecture 3: What is Artificial Intelligence?**
  The science of intelligent machines
  - Computer scientists define intelligence?
  - What are their tools and assumptions?

- **Lecture 4: Artificial Intelligence landmarks**
  Famous programs and findings
  - Which programs have defined the field
  - What can they do, what can’t they do?

Lecture 4: Artificial Intelligence Landmarks

- **4.1 Artificial Intelligence and cognition**
  - AI and cognitive Psychology: Closely linked?

- **4.2 Games and puzzles**
  - Logic Theorist
  - Draughts
  - GPS (*General Problem Solver*)
  - Evaluation: GPS

Lecture 4: Artificial Intelligence Landmarks

- **4.3 Natural language processing**
    - Keywords: Eliza
    - The logic of micro worlds
    - Syntax: SHRDLU
    - The failure of micro worlds
    - The shift to knowledge
    - Semantics and scripts: SAM
    - Evaluation: Natural language processing

Lecture 4: Artificial Intelligence Landmarks

- **4.4 Expert systems**
  - Automated expertise
  - Evaluation: Expert systems

- **4.5 Outlook for traditional Artificial Intelligence**
  - Implications for the Symbolic Search Space Paradigm
  - Hype versus hope?
  - Stalled forever or progressing slowly?

4.1: Artificial Intelligence and Cognition

- Symbolic Search Space Paradigm implies close connection between Artificial Intelligence and cognition research
  - Computers require precise step-by-step instructions
  - Omissions and assumptions of cognition theories highlighted

➡ Forces theoretical precision for cognitive psychologists?

➡ Prompts firmer theoretical advancements?

➡ Fusion led to the *Cognitive Science* movement

AI and Cognitive Psychology: Closely Linked?

- Artificial Intelligence researcher attempts to implement theory of human cognition as part of software

▸ Computer matches human behaviour?

➡ Not clear what can be concluded

  - Theory X is a plausible theory of human cognition?

    [But what about theory Y?]

    OR

- Computer programmer might have used *kludges:* software mimics humans for wrong reasons

  [c.f. Carpenter, Just & Shell, 1990, FairRaven has D2V rule disabled]

AI and Cognitive Psychology: Closely Linked?

- Artificial Intelligence researcher attempts to implement theory of human cognition as part of software

▸ Computer does not match human behaviour?

➡ Also not clear what can be concluded

  - Theory X is *not* a plausible theory of human cognition?

    [Still says nothing about Theory Y]

    OR

- Computer programmer not be very skilled, did not implement theory very well

AI and Cognitive Psychology: Closely Linked?

- ➡ Almost impossible to separate theoretical testing from actual computer program itself
- ➡ Artificial Intelligence and cognitive psychology drifted apart
- ➡ Initial excitement for *Cognitive Science* movement faded away

4.2: Games and Puzzles

- Humans are generally intelligent
- Early AI goal: implement the general heuristics and algorithms of intelligent well-defined problem solving

➡ Embodies *Symbolic Search Space Paradigm*

➡ Domain-specific procedures less interesting

- Partridge (1991): bad paradigms; *Artificial Intellectualism*

➡ Need to understand ill-defined problems

- Persistent findings: programs fail to offer real-world utility

➡ Problem of *scalability*

Logic Theorist

- Newell, Shaw & Simon (1956)
  - Sequence of theorems from *Principia Mathematica* (Russell & Whitehead, 1910), e.g. *Modus Tollens*
  - Program designed to prove these deductively
  - Used a combination of heuristics and trial & error
    - Start state = known truth
    - Logical deductions expand state space
    - Goal = statement to be proved
- Sequence of deductions = proof

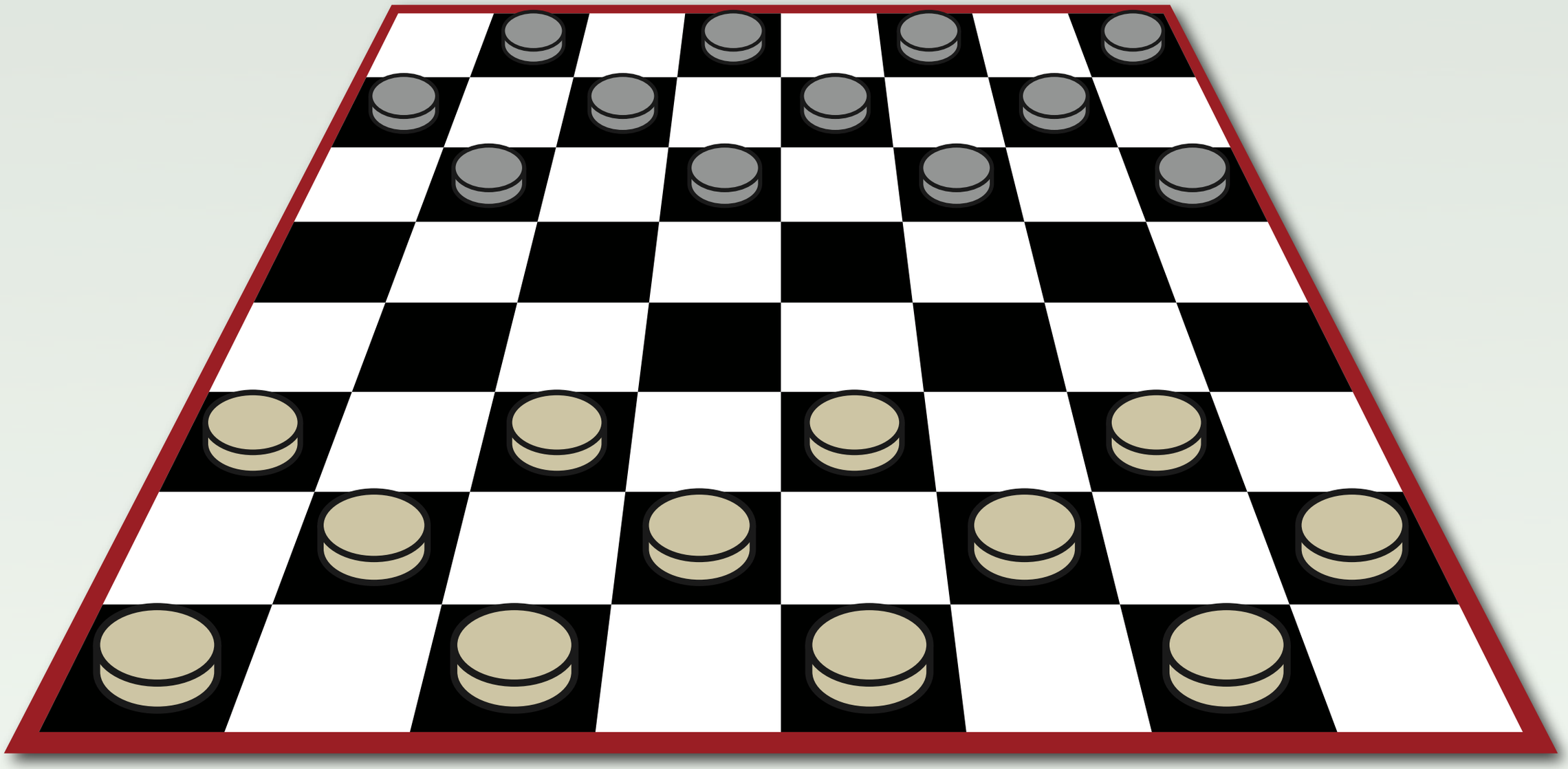
Logic Theorist

- Newell, Shaw & Simon (1956) *cont.*
  - 38 of first 52 theorems proved
  - One of the proofs more elegant than original
  - ➡ Logic *and* creativity?
  - ➡ Logic theorist turned down as co-author(!)

- Evaluation
  - Other 14 theorems were beyond the program
  - ➡ Early example of *brick wall* problem:
    initial rapid progress comes to a sudden halt
  - ➡ What was special about unsolved theorems?

Draughts

- Samuel (1963)



Draughts

- Samuel (1963) *cont.*
  - Created program that could learn from practice
  - Values for position-scoring heuristics could be adjusted as a result of outcomes
  - Could refine these by playing duplicate computers

- ▸ Defeated creator
- ➡ Unexpected behaviour possible
- ➡ Myth disproved: computers only as capable as creators

Draughts

- Samuel (1963) *cont.*
  - Defeated the then champion

    "I have not had such competition from any human being since 1954"
  - Then lost to champion six times in a row

- Evaluation
  - ➡ Scoring systems insufficiently subtle
  - ➡ Program could not create new scoring heuristics, could only reprioritise the ones it was given

GPS (General Problem Solver)

- Newell, Simon & colleagues (1957 to 67)
  - Designed to solve any problem
  - *BUT* had to be encoded in a format that machine could represent
  - Means-ends analysis (sub-goaling) and trial & error strategies for navigating state space
  - Heuristics to prune state space and prevent *combinatorial explosion*

GPS (General Problem Solver)

- Newell, Simon & colleagues (1957 to 67) *cont.*
  - Solved puzzles;
    Missionaries & Cannibals
    Tower of Hanoi
    Water Jugs
    Cryptarithmatic
  - Made deductions

➡ GPS and humans closely matched?

➡ Supports strong symbol system hypothesis?

GPS (General Problem Solver) Evaluation

- Dreyfus (1993)
  - Behaviour does not match humans
  - Some steps (processes) in machine traces were not in protocols

    N&S: subject did not comment on these processes or was unaware of them
  - Some steps in protocols (e.g. two rules simultaneously) not in machine traces

    N&S: subject followed the same method as the computer but reported incorrectly

GPS (General Problem Solver) Evaluation

- Dreyfus (1993) *cont.*
  - ➡ *"It clearly implies a mechanism (maybe a whole set of them) that is not in GPS"*
  - ➡ GPS did not model human behaviour
  - ➡ No evidence for strong symbol system hypothesis [N.B. ***not*** disproven]

- Program needs setting up for each individual task
  - What aspects are unessential vs essential?
  - How are scoring heuristics devised?
  - How should the problem be represented?

➡ Intelligence and insight = creating the problem space

GPS (General Problem Solver) Evaluation

- Haugeland (1985)
  - GPS based on mistaken assumptions
    - All problems are fundamentally similar
    - Problem formulation is a small task compared with problem solving

    ➡ *"GPS was a dream come false"*

- Copeland (1993)
  - Trial and error = desperate last resort, not intelligence

    "Its programmers provide it with a smart representation of a problem and it blunders about until it stumbles across a solution"

GPS (General Problem Solver) Evaluation

- McDermott (1976)
  - GPS is not general, only solves well-defined problems

    "GPS is a stupid program that can solve puzzles"

- Final evaluation

➡ GPS failed in its aim to automate thought

➡ GPS models humans in a narrow sense

➡ But we have learnt a lot from it

➡ SOAR and ACT-R are more sophisticated modern-day successors

4.3: Natural Language Processing

- Very ill-defined problem solving
- Three motivations

  (1) Facilitate human-computer interaction

  (2) Insights into human communication

  (3) Enable document translation (Cold War)

➡ Tension between psychologists/engineers

4.3: Natural Language Processing

- NLP must cope with everyday life
  - No protection via well-defined problems
  - Context precludes dictionary search

Time flies like an arrow
Fruit flies like a banana

On motorcycles, crash helmets must be worn
On escalators, dogs must be carried

➡ Common-sense knowledge essential

Keywords: Eliza

- Weizenbaum (1966)
  - Simulates a Rogerian psychotherapist

    [Never says anything definite]
  - Searches for key words/phrases in input
    - Identifies keywords
    - Matches templates
    - Avoids repetition

➡ No semantic understanding

Keywords: Eliza

- Weizenbaum (1966) *cont.*

… sad …	I am sorry to hear that you are sad
… mother …	Tell me more about your family
… everyone …	Who in particular are you thinking of?
… you __ me …	What makes you think I *don't like* you

Keywords: Eliza

- Only gives an impression of understanding
- Easy to defeat with non-anticipated input
- Simple keyword matching software
  can fool people on different levels
  - Individuals not anticipating deception
  - Commentators: Gardner (1987)

    "… the programs were extremely clever …"

➡ *Eliza effect:* easy to fool people into thinking they are communicating with individuals who understand them

➡ Despite obvious limitations, suggested by some observers that an improved version might replace psychiatrists

Keywords: Eliza

- Weizenbaum (1976)
  - Horrified at the prospect of his software being taken seriously
  - Deeply skeptical of computers being put in positions of responsibility or safety critical situations

➡ Wrote *Computer Power and Human Reason* as a response to perceived dangers

Keywords: Eliza

- Other keyword matching programs:
  - PARRY (Colby, 1975): paranoid delusions
  - BASEBALL (Green, Wolf, Chomsky and Laughery, 1963): database of baseball
  - STUDENT (Bobrow, 1968): simple maths problems

- Final evaluation
  - ➡ Success if limited aspirations
  - ➡ Do we really understand and converse like this?
    - Greene (1986): Yes, sometimes!
  - ➡ But not all the time, so a dead end

The Logic of Micro Worlds

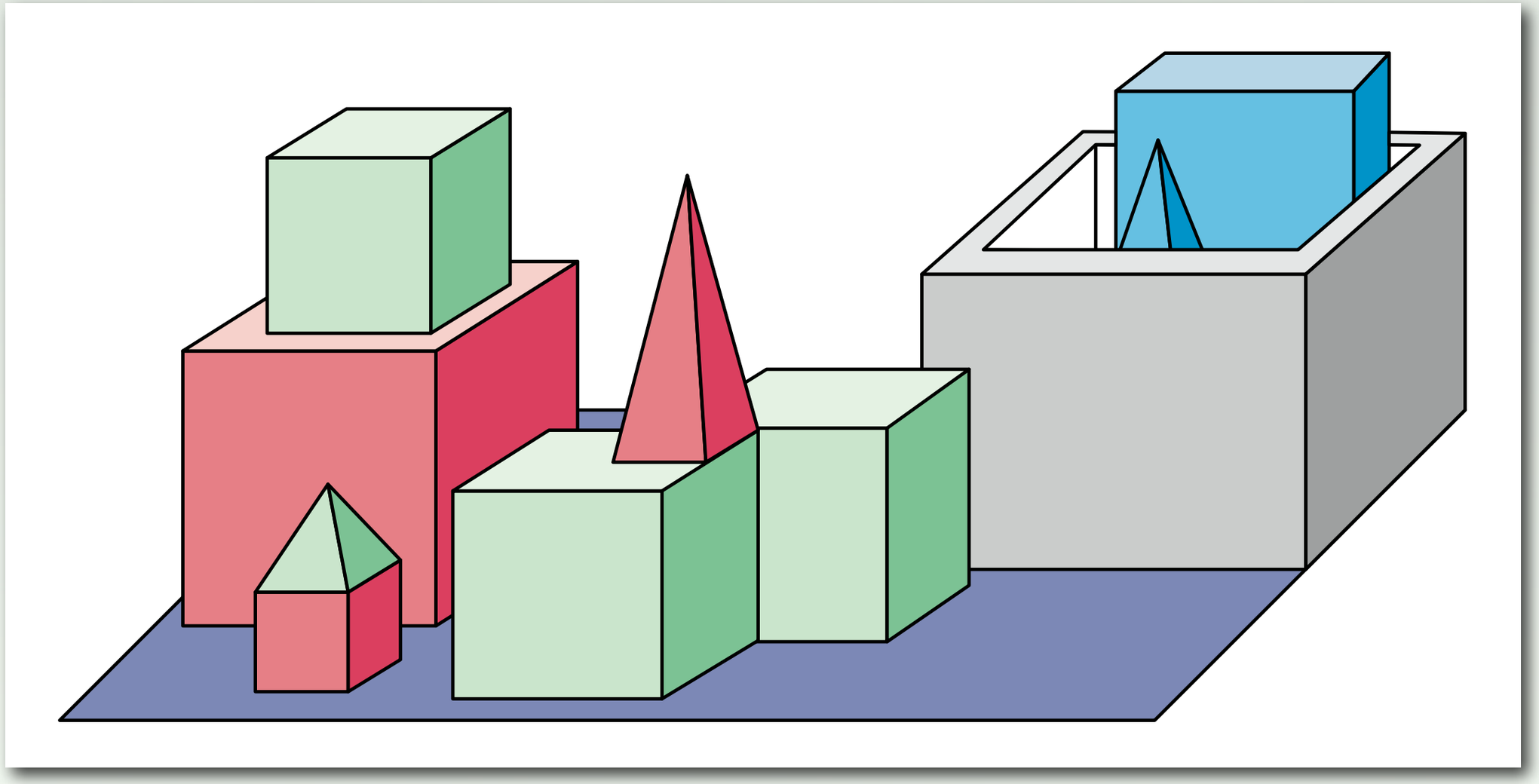
- Micro worlds: imaginary places occupied by virtual robots
- Micro world = a virtual laboratory for creating and understanding communication
- Once micro world is fully formalised and all difficulties addressed, scale up to the real world

➡ Cut through messy reality to find core intelligence?

➡ Create domain-general portable communication module?

Syntax: SHRDLU

- Winograd (1972)
  - SHRDLU: an imaginary micro world of virtual blocks
    - Manipulated by a crane
    - Don’t fall over, get lost, cast shadows



Syntax: SHRDLU

- Winograd (1972)
  - Syntactic processing prioritised
    - Use sentence structure to find deep structure
  - Semantic information available if required
  - Three self-contained modules:
    - *Syntax:* Word meanings/grammar rules
    - *Semantics:* Basic properties of blocks
    - *Knowledge:* Memory of current status
- Modules inter-communicate to resolve ambiguities

Syntax: SHRDLU

- Winograd (1972) *cont.*

(1) Syntax module parses sentences into components (verbs, noun phrases etc.)

put *{the* ***green pyramid****} on {the* ***block*** *in the* ***box****}*

put *{the* ***green pyramid*** *on the* ***block****} in {the* ***box****}*

put is definitely a **verb**
… ***the green pyramid***
… ***the green pyramid on the block***
are **noun phrase** candidates

(2) Semantics module ensures that inferences make sense

e.g. cannot put block on pyramid

Syntax: SHRDLU

- Winograd (1972) *cont.*

  (3) Knowledge module holds the current positions of blocks

  (4) Asks questions if it cannot resolve

  - ➡ Can make inferences and communicate
  - ➡ It can understand its own world (i.e. blocks)?

- Final evaluation
  - ➡ Uses linguistic information unlike Eliza, more intelligent?
  - ➡ Failure to scale to real world indicates crucial omissions

The Failure of Micro Worlds

- Winston (1984)

  "Limited domains of discourse are the E-coli [bacteria] of language"

- Partridge (1991)
  - Bacteria are living things, not human creations
  - DNA, metabolism as in all organisms
  - E-coli itself needs to be understood
  - Physicist micro worlds a better example
    - Ignore friction to understand wheels better
    - ➡ Essence of wheel-ness is preserved

The Failure of Micro Worlds

- Partridge (1991) *cont.*
  - AI researcher micro worlds not the same
    - Ignore reality to understand intelligence better
    - NO! intelligence necessary to negotiate reality

➡ AI micro world programs function because intelligence is not necessary to navigate micro worlds

➡ Inevitable that scaling up to cope with reality will be impossible, no foundations of intelligence to scale

The Failure of Micro Worlds

- Haugeland (1985)
  - Difficult parts of the world require wit and understanding
  - ➡ Micro world has ignored rather than solved problem, programs are gimmicks
- Dreyfus (1993)
  - No such thing as a micro world in real life
  - ➡ Evasions rather than simulations

- Final evaluation
  - ➡ Micro worlds are a blind alley
  - ➡ Unless humans can be persuaded to occupy them

The Shift to Knowledge

- What is required for intelligent behaviour?

➡ 1950s–1970s: general versatile strategies that can solve any problem without domain-specific knowledge

  - General problem solvers
  - General conversationalists

➡ 1970s–1980s: organised domain-specific knowledge

  - Domain-specific conversational topics
  - Expert systems

- Riesberg & Schank (1989)

  "Real thinking has nothing to do with logic at all. Real thinking means retrieval of the right knowledge at the right time"

Semantics and Scripts: SAM

- Schank & Abelson (1977)
  - Communication requires inferences
    - Hard to control inferential explosion

      The student bought the book
    - Micro world restrictions
      - Inferential explosion contained
      - Intelligent inference no longer necessary
  - Real world unconstrained, inferential explosion does matter

➡ Knowledge enables inference to be constrained

➡ Knowledge must be represented such that

- Essential inferences effortless
- Trivial inferences avoided

Semantics and Scripts: SAM

- Schank & Abelson (1977) *cont.*
  - Scripts
    - Sets of actions/objects/expected values associated with an event
    - Unimportant information not mentioned
    - *Restaurant script* is a frequent example
    - Understanding/inference = matching information with knowledge and expectancies to give educated guesses

Semantics and Scripts: SAM

- Schank & Abelson (1977) *cont.*
  - SAM is top-down (hypothesis driven)
  - Consists of inter-communicating modules
  - Syntax avoided if possible
  - Language is simplified, Schank: verbs can be classed into just twelve categories e.g.
    - *ATRANS:* transfer possession
    - *PTRANS:* transfer location
    - *PROPEL:* apply force

Semantics and Scripts: SAM

- Schank & Abelson (1977) *cont.*
  - Key processes for SAM

    (1) Known words are identified
    e.g. chairs, sofas and benches are seating

    (2) Key phrases/words used to identify script

    (3) Text is mapped onto the slots

    (4) Inferences fill in implicit (unstated) information

  - SAM can answer simple questions about narratives
  - BUT extremely slow
  - BUT Fooled by deviations from scripts

Semantics and Scripts: SAM

- Final evaluation

  ➡ Repair fooling of program with additional scripts, but how many are needed and at what level of detail?

  Typical restaurant script
  Expensive restaurant script?
  Restaurant with bad service script?
  Restaurant with fire alarm script?
  Self-service restaurant script?
  Eat-as-much-as-you-like restaurant script?

➡ Scripts as modelled are static,
what is the origin of scripts?

➡ Implementations are still micro worlds, computer with many scripts merely selects the most appropriate one

Evaluation: Natural Language Processing

- Most programs are an uncomfortable mixture of theory, tricks and knowledge
- Programs only impressive when human is unsuspecting or co-operative
- Which yields impressive snippets of dialogue

➡ Genuine understanding illusive, what might it look like?

Evaluation: Natural Language Processing

- Dreyfus (1993)
  - Even the programs with any success have limited scope and cannot be scaled up
  - When faced with real world, they collapse
  - ➡ $20,000,000 wasted
  - ➡ ***No evidence of proper understanding, lack the ability of a four year old child***

Evaluation: Natural Language Processing

- The *common sense* problem
  - Common sense needed for understanding
  - Implicit knowledge so trivial that being queried about it would seen strange

    NOT *are the Pyramids are in Egypt?*

    BUT *if you visit the Pyramids in Egypt, would your left foot also be in Egypt?*

➡ Absurd to encode all possible common sense as a database of explicitly stated facts

➡ How can computers be equipped so that answering common-sense questions is easy

4.4 Expert Systems

- The most tangible and profitable outcome of AI research
- Reaction to lack of success with general problem solvers
- Logical development of micro words

- Expertise modelled using facts and heuristics
- No necessity for cognitive emulation

- Assumptions
  - Expert performance = possession of correct knowledge
  - Expert knowledge can be codifiable as a set of rules

Automated Expertise

- Implementation issues
  - How should knowledge be represented?
  - How can uncertainties be modelled?
  - How can contradictions be resolved?
  - How can experts yield their knowledge?
- Production systems preferred (sets of production rules):
  - IF **PRECONDITION A** AND **PRECONDITION B**
    THEN **ACTION C** / **DIAGNOSIS D** / **ADDITIONAL TEST E** etc.
- Input = current status/problem
- Output = requests for additional information, requests for further investigations, inferences, recommendations

Automated Expertise

- Difficulties with production rules
  - Knowledge often cannot be expressed as tidy rules
  - Uncertainties and probabilities difficult to model
  - ‘Sanitation’ issues almost impossible to resolve
    - What should be the procedure if two or more rules contradict each other
  - How can production systems be audited to ensure internal coherence?

➡ Very difficult to update production systems

Automated Expertise

- Crucial difference between computers and humans
  - Humans; knowledge speeds us up
  - Computers; knowledge slows them down

➡ A large production-rule knowledge-base
is unwieldy and slow to search

➡ This is not how human knowledge is stored and organised

Automated Expertise

- DENDRAL
  - Identifies chemical compounds from mass spectrograms
  - ▸ As good as a competent chemist

- MYCIN
  - Diagnosis and treatment of bacterial blood infections
  - Over 500 production rules
  - ▸ As good as a competent specialist

➡ Is this Artificial Intelligence?

Evaluation: Expert Systems

- Copeland (1993)
- *"…expert systems are not much more than automated reference manuals - and they have no more understanding of what they are for, or the limits of their applicability, than a conventional manual does"*
- Bobrow and Winograd (1977)
- *"Current systems, even the best ones, often resemble a house of cards (…) which may reach impressive heights, but collapses immediately if swayed in the slightest from the specific domain (even the specific examples) for which it was built"*
- Expert systems are unsophisticated,
  shallow, but even worse …

Evaluation: Expert Systems

- Expert systems are ***BRITTLE:***
  Unanticipated input can make them fail spectacularly
  - Medical systems have been known not to detect transposition of height/weight
  - Cannot work from first principles
    if they do not know the answer
    - Cannot make inductions, e.g. from errors

➡ They have no basic common sense

➡ They have no concept of wider implications of decisions

➡ Even if these can be fixed, what are the ethical issues of replacing experts with computers and technicians?

4.5 Outlook for Traditional AI

- Not witnessed intelligent behaviour
- Performance interesting, not spectacular
  - Computers good at mundane, well-defined tasks, easily captured as simple rules
  - Computers bad at complex, ill-defined tasks, where rules and solutions unclear
  - Computers have no common sense

4.5 Outlook for Traditional AI

- Recurring features:
  - ***Unscalable***

    Successful lab projects derailed by real-world complexity
  - ***Brick wall***

    Promising new directions run into serious difficulties
  - ***Brittleness***

    Unanticipated inputs cause bizarre failures
- Correctness of trajectory cannot be determined

➡ *Is the claim that AI is progressing towards the goal of human intelligence analogous to saying that climbing a tree is progress towards walking on the moon?*

Implications for the SSSP

- Copeland (1993)
  - Very little evidence for success of *SSSP*

    "The achievements of AI research are meagre, even toylike when matched against the overall goal of a computer that operates at human levels of intelligence in the unruly complexity of the real world"
  - AI research is a …

    "latter-day alchemy"

- Partridge (1991)
  - SSSP completely fails to capture/yield insight, imagination and intelligence

Hype Versus Hope?

- Newell and Simon (1957)
  - Four notorious predictions; within ten years:
    (1) A computer will be world chess champion, unless rules bar it from competition
    (2) A computer will discover and prove an important new mathematical theorem
    (3) A computer will write music that will be accepted by critics as possessing considerable aesthetic value
    (4) Most theories of psychology will take the form of computer programs
    (5) [added by Simon in 1965] Machines will be capable within 20 years, of doing any work that a man can do

➡ Some success, but way off the time scale

Hype Versus Hope?

- Big money, high ambition projects have fallen short of aims
- Overblown claims have caused backlashes
  - Minsky (1967)

    "within a generation, the problem of creating AI will be substantially solved"
  - Minsky (1986)

    "the AI problem is one of the hardest that science has ever undertaken"

➡ Exposes researchers to ridicule

➡ Corresponding reductions in funding

➡ Reduces status for the field

Hype Versus Hope?

- Copeland (1993)
  - Many more grand claims, still no obvious basis in fact
  - E.g. Schank believes that his programs understand conversational English

➡ Claims by researchers are so wild that may appear deceptive

➡ Optimistic claims necessary to give a new field momentum?

Stalled Forever or Progressing Slowly?

- Dreyfus (1993)
  - Four categories of problem:

    (1) *Associationistic*

    Solved by recall, trial and error, habits and knowledge

    - Easy for computers; simple rules and memory searches

    (2) *Simple Formal*

    Well-defined problems with a simple state space

    - Easy for computers; algorithms

Stalled Forever or Progressing Slowly?

- Dreyfus (1993) *cont.*
  - Four categories of problem:

    (3) *Complex Formal*

    Well-defined problems with a huge state space (chess)

    - Computers uncomfortable with these, need heuristics

    (4) *Nonformal*

    Ill-defined problems, language understanding, etc.

    - Computers have never succeeded and never will

Stalled Forever or Progressing Slowly?

- Dreyfus (1993) *cont.*
  - AI is a degenerating research paradigm
  - Promise and initial impressive achievements; expansion; unexpected setbacks; stagnation; decay

    "… the speed of collapse of the [AI] research program has taken everyone (…) by surprise"

    "Twenty-five years of AI research has failed to live up to any of its promises and has failed to yield any evidence that it ever will"

Stalled Forever or Progressing Slowly?

- Or will barriers to success be overcome?
  - Haugeland (1985)

    "I am not really convinced that [AI] is impossible, on the other hand, I'm certainly far from convinced that it is inevitable."

  - Winograd (in Nilsson, 2010)

    "Relevant science may take decades or more to get to the point where the initial ambitions become realistic"

- **Lecture 5:** Why did it all go wrong?
- **Lecture 6:** Can non-traditional approaches save the day?

Major Sources

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