Introduction to AI

KNOWLEDGE REPRESENTATION

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ideal world (items 2–5)

real world (items 6–9)

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1. Knowledge: AI takes another route

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1.How far can you go with plain search?

- **Medical diagnosis** (AI task, MYCIN)
  - Hundred of symptoms
  - If considered as a whole → huge state-space
  - Data:
    - All information from the patient before any deduction
    - Silly or illogical questions (imagine asking a man for pregnancy)
- **Change of paradigm**: use knowledge to guide and limit search
  - In the same way humans do to narrow possibilities
  - Focus on what is relevant
  - Perform search in a different way

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1.Information and knowledge

- **Information:** set of basic data without interpretation (of a problem)
- **Knowledge:**
  - high level description of that model that structure the experience from a domain and allows the interpretation of the basic data.
  - symbolic
- Example: the blood test 
  - Information: the numerical data from the test
  - Knowledge: the concepts and the reasoning that allows to interpret these values as normal or problematic for a particular person (anaemia, leukopenia...)

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1.Knowledge: Representation and Types

Representation: knowledge represented in data structures to be automatically operated by a computer program.

- **Declarative:** expressed in a way that is directly accesible by humans
  - Inheritable : concepts with a hierarchical structure that base their inference on inheritance (ontologies)
  - Logical: expressed by logical formulas and derived by logical inference (rules)
- **Procedural:** hidden in particular procedures (algorithms) executed on knowledge data structures (simple relations in semantic nets) (complex procedures among facts)

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1.What is symbolic KR about?

Symbols

Propositions

A — yesterday rained

B — I will learn a lot at the UAB

C — that person loves me

Given a problem, concepts could be expressed as propositions

Propositions have two possible truth values: *true* and *false*

Producing new knowledge

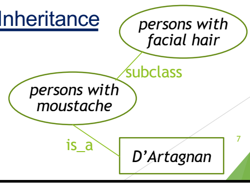
Modus ponens (expressed as logical implications)

A is *true*

A → *B* is *true*

it is legal to conclude that *B* is *true*

Inheritance



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2. Knowledge Representation and Logic

- Logic:
  - branch of mathematics about legal deductions and propagation of truth
  - Georg Boole, Bertrand Russell...
- Knowledge Representation:
  static declarative knowedge + current problem instance = produce new knowledge that allows to solve the problem
- You want to operate knowledge to derive new knowledge
- Logic appears as a natural language for declarative KR
  - Because of that, logic is in all AI textbooks

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2. Propositional logic

- Propositions: A, B, C…
  - A: *today is sunny*
  - B: *we enjoy a walk in nature*
  - C: *my tailor is rich*
- Truth values: true (1), false (0)
- Logical operators: negation (¬A), conjunction (A^B), disyunction (AvB), implication (A→B), equivalence (A←→B)

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2.KR: Propositional logic – Truth tables

negation

A	¬A
1	0
0	1

disjunction (or, v)

A	B	AvB
1	1	1
1	0	1
0	1	1
0	0	0

conjunction (and, ^)

A	B	A^B
1	1	1
1	0	0
0	1	0
0	0	0

implication (imp, →)

A	B	A→B
1	1	1
1	0	0
0	1	1
0	0	1

equivalence (equiv, ←→)

A	B	A←→B
1	1	1
1	0	0
0	1	0
0	0	1

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2.KR: Propositional logic – Truth tables (II)

- Perfect way to check the legal inferences:
- (A→B) ←→(¬AvB) (??)

both have the same truth tables

A	B	A→B	¬AvB	(A→B)←→(¬AvB)
1	1	1	1	1
1	0	0	0	1
0	1	1	1	1
0	0	1	1	1

Tautology: a sentence that is always true

- Theorems are tautologies.

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3. *Modus ponens* – Production rules

- Modus ponens (since Aristotle):
  - If A is *true*, and
  - A→ B is *true*, then it is legal to deduce that
  - B is *true*
- A single line of the truth table

A	B	A→B
1	1	1
1	0	0
0	1	1
0	0	1

- Production rules: to be used for modus ponens inference only (A=>B) [in logical terms, they are Horn clauses]

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3. Production rules

- Rules:
  - Two parts: left hand side (conjunction of conditions on facts), righ hand side (a conclusion on a fact); condition — action pairs
  - Interpreted by an inference engine (that performs chaining)
  - With a solid theoretical (logical) base
- Firing: when condition is true, action is added to the fact base
- A rule:
  - codifies a simple (elemental) inference step
  - solution: involves a sequence of firing rules
- Declarative knowledge: although attractive, it is difficult to maintain
- Monotonicity: always adds new facts

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3. Production rules in expert systems

Internal deductive space divided in two:

- Facts base:
  - facts that are data of the current case
  - they can be: initial, derived

  age=48 pain=yes blurry vision=yes
  meningitis=may_be

- Rule base: static knowledge on a particular domain, codified in rules
  - *If gramnegative and rod and anaerobic => bacteroides [0.6]*

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3. Production rules: example

PREMISE (SAND(SAME CNTXT INFECT PRIMARY-BACTEREMIA)
(MEMBF CNTXT SITE STERILESITES)
(SAME CNTXT PORTAL GI))
ACTION (CONCLUDE CNTXT IDENT BACTEROIDES TALLY .7)
If (1) the infection is primary-bacteremia, and
(2) the site of the culture is one of the sterilesites, and
(3) the suspected portal of entry of the organism is the gastro-intestinal tract,
then there is suggestive evidence (.7) that the identity of the organism is bacteroides.

A rule from the MYCIN knowledge base. SAND and $OR are the multivalued analogues of the standard Boolean AND and OR.

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3. Production rules: chaining

Rules are always fired fron condition (IF) to action (THEN); however, the strategy of the inference engine could be:

- Forward chaining: from the facts, any rule is fired as soon as satisfied
- Backward chaining: from the goals, as follows
  - A goal is established
  - Firing is limited to: (i) the rules that conclude that goal, (ii) the rules that conclude the conditions of (i), etc.
  - Inference is more focused on the system objectives
  - If external conditions are asked, ES behaviour is more meaningful for the human operator

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3. Production rules: chaining

- Forward chaining
  - Repeat until all aplicable rules have been processed
    - Match the facts in the set of facts against the conditions of the rules
    - Those rules whose conditions are fulfilled are potentially aplicable
    - Select one of these rules
    - Apply the rule by adding the conclusión to the set of facts
- Backward chaining:
  - Select a goal
  - Repeat until the goal is achieved
    - Look for rules whose conclusion match the goal
    - All matched rules become potentially aplicable
    - One of these rules is selected
    - Its conditions are new subgoals to be achieved

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4. Semantic networks

Directed graph:

- nodes are concepts
- arcs are labelled with relations
- Codify some static knowledge of the problem domain
- Simple concepts
- Simple inferences are made traversing the graph

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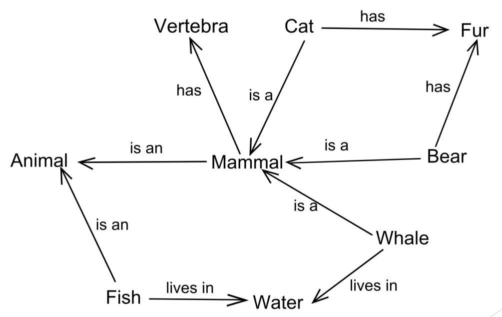
4. Semantic networks: example



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4. Frames

- Structured objects (slot-and-filler architectures)
- Very close to recods in Computer Science
- Stereotypical situations
- Same motivation as semantic nets, but for complex objects
- Relations of semantic nets → appear as attributes in frames

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4. Frames: example

SLOTS	VALUES
Title	Artificial Intelligence
Genre	Computer Science
Author	Peter Norvig
Edition	Third Edition
Year	1996
Page	1152

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5. Ontologies

- Definition: An explicit, machine-readable specification of a shared conceptualization
- Motivation:
  - Desire to share structure of domains across applications
  - To separate operational knowledge (rules) from static domain conceptualization
- Developed for:
  - domain specific
  - ambition: a general ontology
    - with the help of Wikipedia
  - inference: inheritance

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5. Ontologies (cont.)

- Operationally, an ontology is a hierarchy of categories
- Relations:
  - Class—subclass—member → inheritance
  - Part_of, composed_objects
- Some ontologies:
  - Dbpedia
  - TextRunner
  - OpenMind

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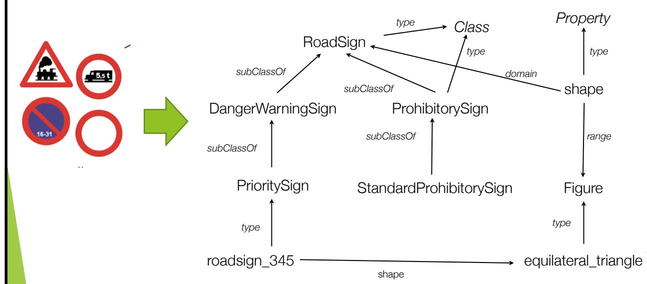
5. Ontologies: example



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6. Default reasoning

Does Tweety fly?

- Tweety is a bird (belongs to the BIRD category)
- and birds fly, so Tweenty flies (simple inheritance)

This is Tweety,
it has a broken wing → Tweety does not fly

- Default reasoning:
  - Inherit values
  - Unless other some more specific information is available

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6. Default reasoning (cont.)

- What happens if, after performing reasoning, one knows that Tweety has a broken wing?
- Non-monotonic reasoning:
  - Capacity to remove previous deductions when new facts are known that contradict old ones:
    - Humans are very good at that; not the case for machines
  - Inferred facts do not grow monotonically
  - Assumption-based Truth Maintenance Systems (ATMS)
  - Circumscription (logical approach)

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7. Metaknowledge

Knowledge about knowledge:

- Control knowledge:
  - How deduction is made
  - Usually local to KB (knowledge base) parts
- Special rules (metarules)
  - Establishing goals and strategies
  - Focusing deduction on a group of rules
  - Have preference on normal rules
- Execution:
  - Rules: at the domain level
  - Metarules: at metalevel

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7. Metaknowledge (cont.)

- Example:
  - KB = group of KB modules
  - KB module = goals, rules, metarules
  - KB module goal: pursued by the rules of module
  - KB modules are activated according to metarules
  - There is an INIT module, that activates first

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8. Uncertainty

- Our knowledge of the world is always incomplete:
  - Causal inferences are not 100% valid
    - Odd cases, exceptions
    - Especially in the medical realm
  - Facts are partially known, often qualitative:
    - Weather report: partially cloudy, little rain,
- (Real) Knowledge representation has to be extended to haldle uncertainty for all its types: facts / rules /metarules
- Two basic forms to handle uncertainty:
  - Probabilities
  - Fuzzy logic

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8. Uncertainty: probability (frequentist)

- Probability is applied to well-defined propositions: only makes sense *true* or *false*. Ex. Are you pregnant?
- Frequentist approach:
  - Pr (event i) = #favourable cases/#possible cases

    Ideal

    world
  - Applied to cards games, balls, etc.
  - Not of much use in AI

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8. Uncertainty: conditioned probability

- Prior probability:
  - Before an event happens
  - Usually based on reasons of regularity, symmetry…
- Conditioned probability:
  - After an event *E* that changes probabilities
  - $Pr(X|E)$ = probability of *X* given that we observed *E*
  - Posteriori or conditioned probability
  - Bayes' formula connects prior and conditioned probabilities

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8. Uncertainty: conditioned probability example

- Example: breaking the code of Enigma (SWW):
  - Enigma machine: encription/decription of messages
  - British (Turing) broke the encription
  - Prior probability of each letter: uniform
  - Events: common subsentences in messages
    - Weather report
    - Heil Hitler!
  - Modify the probability of each letter: no longer uniform (a posteriori, conditioned probability)

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8. Uncertainty: fuzzy logic

- Intuitive approach to handle uncertainty; adequated for graded propositions
- Imagine: *Fred is Young (he could be very young, half young, not young)*
  - True if *Fred* is 19 (*Fred* belongs completely to the fuzzy set YOUNG)
  - False if *Fred* is 50 (*Fred* does not belong to the fuzzy set YOUNG)
  - In between if *Fred* is 30 (*Fred* belogs partially to the fuzzy set YOUNG)
- How *Fred* belongs to the fuzzy set YOUNG
  - Membership function: Instead of 0 or 1 (as for classical sets), it is a number in the interval [0, 1]
- Fuzzy logic also allows graded qualifiers of natural language: *Fred is very young*
- In fuzzy logic, intermediate degrees of truth between [*false*, *true*]

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8. Uncertainty: certainty factors

- In expert systems, the degree of confidence represented by certainty factors in:
  - Facts
  - Rules
- Combination:

  degree of confidence of condition
  degree of confidence of rule
  to produce
  degree of confidence in conclusion

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9.Knowledge Engineering

- Develop the procedures to interpret the declarative knowledge
  - Rule inference
  - Inheritance
- Organize the declarative/procedural knowledge for:
  - Performance
  - Validation
  - Maintenance (hard task!)
- Generate the adequate data structures for handling knowledge at run time
  - Facts base
  - Goals in backward chaining

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10.KR names: John McCarthy

- (1927 – 2011)
- MIT, full profesor Stanford
- One of the big old names
- Father of AI (conference of Darmouth)
- Proposed circumscription (nonmonotonic reasoning)

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10.KR names: Marvin Minsky

- (1927 – 2016)
- Full professor MIT
- One of the founders (conference of Darmouth)
- Worked on perceptrons
- Proposed frames (complex objects in semantic networks)

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10.KR names: Bruce Buchanan

- (?)
- Full profesor Carnegie-Mellon (Pittsburg)
- Many contributions to expert systems
- MYCIN (Univ. Stanford)

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10.KR names: Ronald Branchman

- (?)
- University / Company ??
- Many contributions to knowledge representation
- KL-ONE

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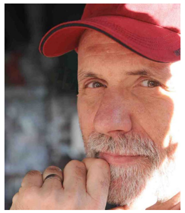
10.KR names: Hector Levesque



- (?) Canadian
- Full profesor Toronto univ.
- Many contributions to knowledge representation
- Theoretical work

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10.KR names: MYCIN

- Diagnoses blood infections (in the 70s)
- Early ES in medicine
  - Rules
  - Centainty factors
  - Forward and backward chaining
  - Usability by doctors
  - Ethical issues unsolved
- Caused an early ES shell: EMYCIN

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10.KR names: KL-ONE

KL-ONE (80s)

- Knowledge representation Language:
  - Semantic networks
  - Frames
  - Inheritance
- Developed by Ronald Branchman and others

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10.KR names: CYC

- 80’s
- An attempt to make a massive symbolic artificial intelligence
- Capture common sense knowledge
- It was unfinished
- May of KR issues were reworked

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11.Wrap-up

- Symbolic Knowledge Representation
- Main reserch topic in 80s, 90s
- Somehow, now is not in the AI main stream
- Nevertheless, it is useful to know the achievements and contributions on this topic
  - To understand current symbolic AI systems
  - To get familiar with existing AI tools

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11.Wrap-up (cont.)

- Symbolic Knowledge Representation
- Logic
- Rules
- Semantic networks
- Frames
- Ontologies
- Default reasoning
- Metaknoeledge
- Uncertainty
- Knowledge engineering

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Further reading

- Russel & Norvig 3rd ed:
  7.1, 7.3, 7.4, 7.5, 12.1, 12.2, 12.5, 12.6
  Bibliographical Notes chapters 7 and 12
- Ginsberg, *Essentials of Artificial Intelligence*
  2.3, 9.3, 11.1, 12.1
  Further Reading chapters 2, 9, 10, 12

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