Knowledge representation and reasoning
Lecture 1: Introduction

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Plan of the lecture

1. Admin
2. What is this module about
3. Examples of knowledge-based systems
4. Plan of the module

Essential module information

- From this year: 20 credits
- 2 lectures a week + one hour lab/problem class
- 75 % exam, 25 % coursework (5 small assignments marked in the lab)
- Lecture 1: Monday 12:00-13:00 in JBSouth A25
- Lecture 2: Thursday 09:00-10:00 in JC-EXCHGE-B.LT1
- Lab: Monday 17:00-18:00 in A32 (there is one today!)
- Office hour: Friday at 11:00

More module information

- This year module page is on moodle
- Previous exam papers and answers are on `http://www.cs.nott.ac.uk/~psznza/G53KRR`
- note that this module had different convenors and content in 2014-15 and 2015-16 and exams were different
- textbook:

  Ronald Brachman and Hector Levesque. *Knowledge Representation and Reasoning.* Elsevier, 2004
- module page has a link to Levesque's lecture slides; I will be mostly using a board, so prepare to take notes!

What is this module about

- How can knowledge be represented symbolically and manipulated in an automated way by reasoning programs
- Knowledge: some information about the world
  - medical information about some particular set of diseases: what causes them, how to diagnose them
  - geographical data: which city is the capital of which country, population statistics, . . .
  - common sense physics: bodies cannot go through solid walls, . . .
- Representation: how / in which language do we represent this information
- Reasoning: how to extract more information from what is explicitly represented (because we cannot represent every single fact explicitly as in a database)

Knowledge-based systems

- We want to be able to talk about some AI programs in terms of what they 'know'
  - (which corresponds to taking 'intentional stance' towards those systems, ascribing them human characteristics - for why this may be useful, see Daniel Dennett)
- ... and not just talk about what they know but also have something to point to in those systems corresponding to 'knowledge' and determining their behaviour, namely *explicitly represented symbolic knowledge*

Example (Brachman and Levesque)

Two Prolog programs with identical behaviour:

```
printColour(snow) :- !, write("It's white.").
printColour(grass) :- !, write("It's green.").
printColour(sky) :- !, write("It's yellow.").
printColour(X) :- !, write("Beats me.").
```

and

```
printColour(X) :- colour(X,Y), !, write("It's "),
write(Y), write(".").
printColour(X) :- write("Beats me.").
colour(snow, white).
colour(sky, yellow).
colour(X,Y) : - madeof(X,Z), colour(Z,Y).
madeof(grass, vegetation).
colour(vegetation, green).
```

Which one is knowledge-based

- Only the second program has explicit representation of ‘knowledge’ that snow is white
- the second program does what it does when asked for the colour of snow *because of* this knowledge. When `colour(snow, white)` is removed, it will not print the right colour for snow.
- what makes the system knowledge-based is not
  - the use of a particular logical-looking language like Prolog
  - or having representation of true facts (`colour(sky, yellow)` is not)
  - or having lots of facts, or having a complex structure
- rather, it is *having explicit representation of knowledge which is used in the operation of the program*

Definition of knowledge-based systems and knowledge bases

- Knowledge-based systems are systems for which intentional stance is grounded by design in symbolic representation
- The symbolic representation of knowledge is called a knowledge base.

Examples of knowledge-based systems

- Various expert systems
  - MYCIN (1970s, Stanford University)
  - XCON (1978, Carnegie Mellon University)
- Perhaps most famous knowledge base: CYC (1980s, Douglas Lenat, Cycorp, Austin, Texas)
- Ontologies
  - Snomed CT `http://snomed.dataline.co.uk/`
  - Gene ontology `http://www.geneontology.org/`
- Google Knowledge Graph
- (Parts of) IBM Watson

MYCIN

- 1970s, Stanford University (Edward Shortliffe, Pat Buchanan)
- Production rule system (we will see them later in the course)
- Purpose: automatic diagnosis of bacterial infections
- Lots of interviews with experts on infectious diseases, translated into rules (knowledge acquisition is a non-trivial process; also see later in the course)
- approximately 500 rules

Example MYCIN rule

Rule in LISP:

```
RULE035
PREMISE: ($ AND (SAME CNTXT GRAM GRAMNEG)
                (SAME CNTXT MORPH ROD)
                (SAME CNTXT AIR ANAEROBIC))
ACTION: (CONCLUDE CNTXT IDENTITY BACTEROIDES TALLY
.6)
```

English translation:

IF:

1. the gram stain of the organism is gramneg, and
2. the morphology of the organism is rod, and
3. the aerobicity of the organism is anaerobic

THEN: There is suggestive evidence (.6) that the identity of the organism is bacteroides

More about MYCIN

- some facts and some conclusions of the rules (as above) are not absolutely certain
- MYCIN uses numerical *certainty factors*; range between -1 and 1
- (reasonably involved) rules for combining certainty factors of premises, with the number in the rule (as 0.6 above) into a certainty factor for the conclusions
- later it turned out that MYCIN's recommendations would have been the same if it used only 4 values for certainty factors
- MYCIN was never used in practice (ethical and legal issues)
- when tested on real cases, did as well or better than the members of the Stanford medical school

XCON

- John McDermott, CMU, 1978
- eXpert CONfigurer - system for configuring VAX computers
- production rule system, written using OPS5 (language for production systems, implemented in LISP)
- 10,000 rules
- used commercially

Cyc

- The Cyc Knowledge Server is a very large knowledge base and inference engine
- Developed by Cycorp: `http://www.cyc.com/`
- It aims to provide a deep layer of ‘common sense knowledge’, to be used by other knowledge-intensive programs

Cyc knowledge base

- Contains terms and assertions in formal language CycL, based on first-order logic, syntax similar to LISP
- Knowledge base contains classification of things (starting with the most general category: Thing), and also facts, rules of thumb, heuristics for reasoning about everyday objects
- Currently, over 200,000 terms, and many human-entered assertions involving each term; Cyc can derive new assertions from those
- Divided in thousands of 'microtheories'

Cyc knowledge base

- General knowledge: things, intangible things, physical objects, individuals, collections, sets, relations...
- Domain-specific knowledge, for example:
  - Political geography: general information (e.g. What is a border?) and specific information about towns, cities, countries and international organizations
  - Human anatomy and physiology
  - Chemistry

Snomed

- Snomed CT: Systematized Nomenclature of Medicine Clinical Terms
- Developed by College of American Pathologists and the NHS
- Clinical terminology (with formal definitions)
- Designed for unambiguous recording of data and interoperability with software applications
- Uses ontology language (different from first order logic) EL++
- Approx. 400 000 concepts, 1 million terms and 1.6 million relationships

Snomed: example

Concept: 32553006 - Hangover

Descriptions:

Synonym: hangover effect
Synonym: hangover from alcohol

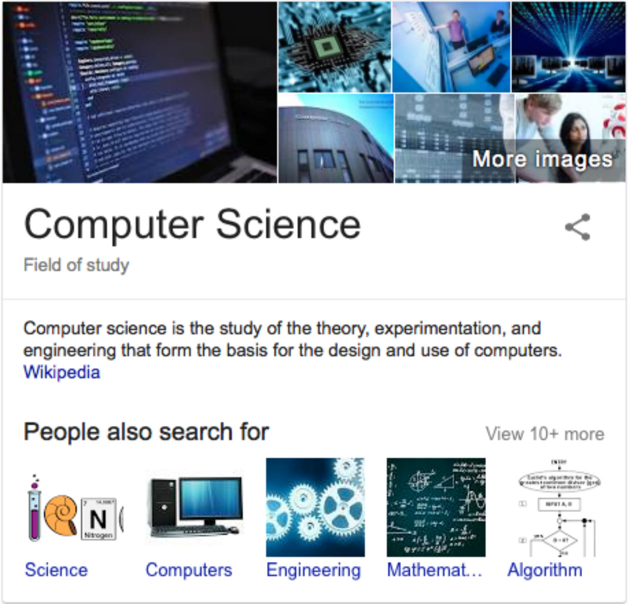
Relationships:

(is a) 228273003 - Finding relating to alcohol drinking behavior
(causative agent) 311492009 - Ingestible alcohol

Google's Knowledge Graph

- based on an earlier knowledge base, Freebase (bought by Google in 2010)
- is used to enhance search results by displaying Wikipedia-style entry in an infobox alongside search results
- there is also a Google API which allows programmers to use Knowledge Graph
- used in Google Assistant and Google Home to answer questions

Examples of knowledge-based systems



Watson

- developed at IBM by a team led by David Ferrucci
- question answering system (originally developed to play Jeopardy)
- has access to terabytes of data (all Wikipedia pages, other encyclopedias)
- Jeopardy instance of Watson had a knowledge base, but
- mostly used statistical correlation methods in plain English text to find answers to questions such as, which city has airports named after a WWII hero and a WWII battle
- other instances of Watson are used in medicine (the first commercial application was decision support in lung cancer treatment)

Watson playing Jeopardy

Long standing split in AI

- explicit symbolic representation (symbolic AI); this module is symbolic AI
- non-symbolic AI: behaviour robotics, (deep) learning
- machine learning saves us from having to hand-code explicit reasoning rules and statements about the world; some tasks which humans can easily do are unlikely to every be formalisable
- on the down side, hard to say exactly what a machine-learned program will do next
- are there things that machine learning/collecting information from the web will never be able to do?

Winograd Schema Challenge

- Hector Levesque (2013): Winograd Schema Challenge (to replace Turing test)
- requires understanding the meaning of language vs exploiting statistical correlations
- Examples:
  - The trophy would not fit in the brown suitcase because it was too big. What was too big?
    1. the trophy
    2. the suitcase
  - Joan made sure to thank Susan for all the help she had given. Who had given the help?
    1. Joan
    2. Susan

Winograd schema challenge

- there is a competition running since 2016 called Winograd Schema Challenge sponsored by Nuance Communications
- there was a successful individual project at the School by George Hallam in 2013/14 to answer some types of Winograd schema questions
- represented knowledge about fitting things in containers etc.
- used first order reasoning (resolution) to produce answers

Today's lab: START

- I could not find any online instance of Watson
- Try to determine whether START is using reasoning or just looking things up on the internet
- START Natural Language Question Answering System, MIT, 1993
- `http://start.csail.mit.edu`
- You can also use the lab time to ask me questions about the module

Plan of the module

- First order logic (3 lectures); cw1 8/10/2018
- Resolution (4 lectures); cw2 22/10/2018
- Horn clauses, backward chaining, forward chaining (3 lectures); cw3 5/11/2018
- Description logic/ontologies (2 lectures); cw4 19/11/2018
- Defaults/non-monotonic reasoning (2 lectures)
- Reasoning about actions and planning (4 lectures); cw5 3/12/2018
- Uncertainty/bayesian networks
- Lifecycle of a knowledge based system

Recommended reading for the next lecture

- Hector Levesque. On our best behaviour. Artificial Intelligence, Volume 212, 2014, pages 27-35. (on moodle)
- Brachman and Levesque, chapter 2 (The language of first-order logic).