

COMP60162

Knowledge Representation and Reasoning

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Overview

- Do check the website regularly for announcements
- Thursdays in Period 2: 10 Nov – 12 Dec (coursework 15 Dec - 19 Dec)
- Option for FM and AI specialisations
- Lectures presented in 4 parts:
 - ▶ Part I (Sattler, 3) Early KR formalisms, first-order logic
 - ▶ Part II (Schmidt, 8) Modal logic
 - ▶ Part III (Schmidt, 4) Description logic
 - ▶ Part IV (Sattler, 10) Extensions and applications

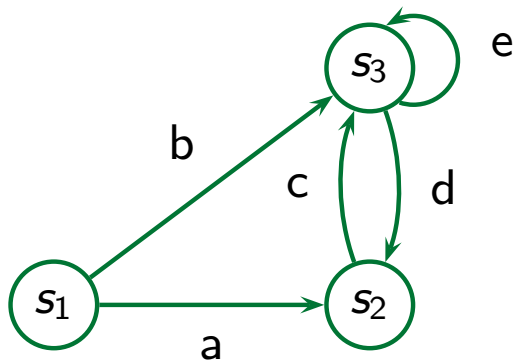
Part I: Early KR formalisms and first-order logic

- Early AI/KR research was very enthusiastic with very high goals
 - ▶ early KR formalisms were quite attractive
 - ▶ but also came with several problems which are well understood today
- Why first order logic? What is missing in propositional logic?
 - ▶ FOL allows to describe different objects and their relationship
 - ▶ FOL is “the unifying formalism” of many KR formalisms

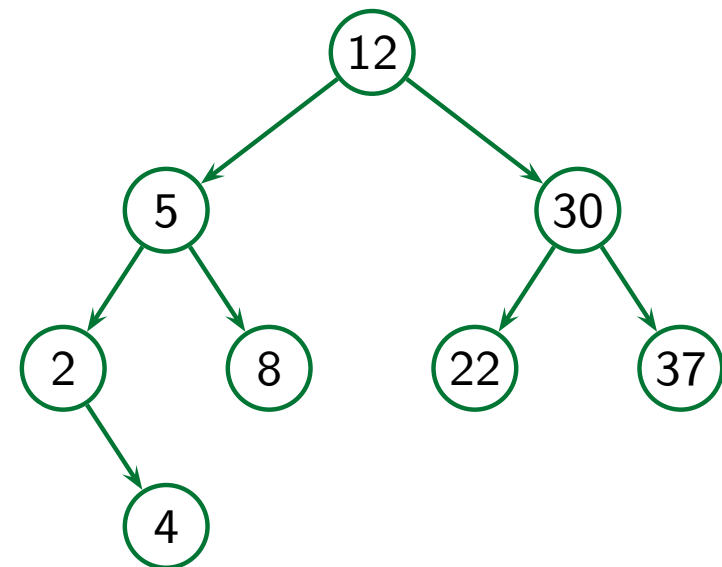
Why modal logic? Why description logic? (1)

First-order logic is a very expressive language, can capture wide range of knowledge \rightsquigarrow Why ML? Why DL?

- ML and DL are expressively weaker than FOL.
- ML and DL are simpler, more natural languages, yet powerful enough to describe useful structures:



transition systems used to
model program executions



trees

Why modal logic? Why description logic? (2)

- ML and DL are very popular in CS and AI, have been “reinvented” many times.
- There are many applications.
- Modal and description logics have nice computational properties.
 - ▶ Reasoning in first-order logic is **undecidable**
many MLs and DLs are **decidable**
some MLs and DLs are **undecidable**

We will mostly study decidable logics.

- ▶ The MLs and DLs we study have **nice computational complexity**.

Part II: Modal logic

- Modal logics are a *formal way* of handling notions of **knowledge**, **belief**, time, actions, necessity, possibility, etc ('modalities')
- Modal logics allows us to model different modes of truths:
 - ▶ **Gordon Brown is the prime minister of Britain**
is true now, but will not be **true forever**.
 - ▶ **The square root of 625 is 25**
is true (by definition), but it is not **known** by everyone.
 - ▶ **This is the best of all possible worlds**
may or may not be true, but there are people who **believe** it and others who don't.

Sample specifications from multi-agent systems

Op.	Name	Meaning
\mathbf{K}_i	knowledge operator	agent i knows
\mathbf{B}_i	belief operator	agent i believes
\bigcirc	next operator	after next election

$\mathbf{K}_{\text{Adam}}(\text{prime_minister}(\text{Gordon}, \text{GB}) \wedge$

$\bigcirc (\text{prime_minister}(\text{Gordon}, \text{GB}) \vee \neg \text{prime_minister}(\text{Gordon}, \text{GB}))$

Adam knows, Gordon is currently the p.m. and after the next election Gordon will either be p.m. or not.

$\mathbf{K}_{\text{Eve}}\text{prime_minister}(\text{Gordon}, \text{GB}) \wedge \mathbf{B}_{\text{Eve}} \bigcirc \neg \text{prime_minister}(\text{Gordon}, \text{GB})$

Eve knows Gordon is currently the p.m. and believes after the next election Gordon will not be p.m.

Part III: Description logics

- Description logics are about
 - ▶ modelling world knowledge, i.e. ‘objective knowledge’ of a particular domain of application
 - ▶ and reasoning about it
- DL systems have similar applications as databases but are more flexible and more expressive
- DLs systems are used for modelling ontologies; important for semantic web

Motivating example

A classical database stores information in a series of tables which represent relations.

Query: Is there a grandfather?

Answer: No

Why not?

What is missing is a definition of the concept **grandfather** (a view).

Suitable **concept definitions** in description logic would be:

$$\text{grandfather} \doteq \text{male} \sqcap \exists \text{parent_of} . \exists \text{parent_of} . \text{human}$$
$$\text{male} \sqsubseteq \text{human}$$

parent_of		male
Phillip	Charles	Phillip
Charles	William	Charles
...	...	William
...

Services of description logic systems

- DLs allow the description of both concrete (database) and abstract information (concept definitions \rightsquigarrow ontologies).
- Sample **inferential services**:
 - ▶ consistency: KB consistent? **grandfather** consistent?
 - ▶ subsumption: **grandfather** subsumed by **human**?
 - ▶ instance checking: **Charles** an instance of \exists parent_of.human?
 - ▶ querying KB
- In contrast to databases, DL systems can handle **incomplete information**.

Part IV: Extensions and applications

- **ICOM:** a tool for intelligent conceptual modeling built to design and reason about ER/UML schemas, based on DLs
- **Non-standard reasoning services:**
 - ▶ applying DLs requires more than classical logical reasoning (validity, satisfiability, etc)
 - ▶ to support **domain experts** which are not DL experts,
 - ▶ e.g. to add new concepts into a knowledge base
 - ▶ Example NSRS: approximating concepts
computing the least common subsumer of some concepts
computing the most specific concept for an individual, etc.

Part IV: Extensions and applications

- **Temporal DLs:**

- ▶ so far, DLs were **static**
- ▶ to express knowledge about **changes**, actions, processes, etc., requires a notion of **time**, e.g.,
- ▶ CS_Student **implies eventually** (Rich **or** Famous)

- **Defaults:**

- ▶ so far, we only have **strict axioms** Bird **implies** CanFly
- ▶ some applications want **default axioms**
Bird **implies_by_default** CanFly (because of Penguins, broken wings, oil disasters, etc.)
- ▶ how to extend FOL or DLs with such “defaults”

Pre-requisites

- Some knowledge of logic and formal methods
- Not covered by lectures but part of first exercise sheet:
 - ▶ **Elementary set theory**
What is a set, a relation, a function, set operations (intersection, union, etc), properties of binary relations (reflexivity, symmetry, transitivity, etc).
 - ▶ **Propositional logic** (Boolean logic)
syntax, logical operators \wedge , \vee , \neg , \rightarrow , etc, truth tables
 - ▶ **First-order logic**
First order logic formulae, their meaning, validity and satisfiability, translating between natural language and first-order logic.

Reading material

- Course unit does not follow a specific book: copies of the slides are made available.
- Recommended reading material: listed on the course description webpage.
- The books on the webpage are available in the Resources Centre. No need to buy a book for this course unit.
- Copies of any additional papers are available on the web or via the 'E-journals' facility of the main library.

Coursework

- Exercises and assignments are of varying difficulty – some are aimed to consolidate the material of the lectures and are therefore easier.
- Some exercises and assignments are to be done with pencil and paper, some will require the use of tools (SPASS for the ML & DL part, ICOM for the DL application part).
- Assessed essay on a paper related to KR&R.
You'll be given a list of papers from which you choose one.

Assessment

- 60% coursework
 - ▶ 35% for Uli's weekly coursework
 - ▶ 35% for Renate's weekly coursework
 - ▶ 30% for essay
- 40% exam