The FO($\cdot$) Knowledge Base System project

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Introduction: the FO($\cdot$) KBS project

A small course:

- Introduction: motivation, definition of terms
- Lecture 1: the FO(.) language framework
- Lecture 2: the knowledge base system IDP
- Lecture 3: advanced topics

Introduction: the FO($\cdot$) KBS project

The fundamental KRR research question

- Humans experts possess (declarative) knowledge.
- They use it
  - to accomplish tasks
  - to solve problems
  - or to build programs that do this for us (computer science)
- How does this work?

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- How does this work?

- Inherently a KRR research question.
  - (KRR: Knowledge Representation and Reasoning)
- If we ever want to be able to build software systems in a principled way, we will NEED to understand this.
- This places KRR at the foundations of computer science.

State of the art

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- Scientific understanding is partial and scattered over the many fields of computational logic and declarative problem solving.
- One issue that fragments computational logic more than anything else:

the reasoning/inference task

State of the art

- Logics are entangled with a reasoning task:
  - Classical first order logic (FO):
    deduction
  - Deductive Databases (SQL, Datalog):
    query answering & other database operations
  - Answer set Programming (ASP):
    answer set computation
  - Abductive Logic Programming:
    abduction
  - Constraint Programming (CP):
    constraint solving
  - Description logics:
    subsumption $\subseteq$ deduction, other forms of inference
  - Planning languages PDDL :
    planning
  - Temporal logics :
    model checking
  - ...

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A declarative proposition in natural language:

Each lecturer teaches at least one course in the first bachelor

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In the current state of the art, depending on the task to be solved, a different language and system is needed to represent this proposition.

Is declarative knowledge not independent of the task (and hence, of a specific form of inference) ?

An illustration

Question: How to solve a graph coloring problem in a declarative way?

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  - model generation: expand $\mathfrak{A}$ to a model; return $Col^{\mathfrak{A}}$

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- FO was seen exclusively as the logic of deductive reasoning.
  - In some fields, this is still the dominating view.
- Deduction is utterly useless for solving the graph coloring problem.
- Instead, people developed new logics to handle problems like this:
  - Constraint Programming Languages
    - Ilog, Zinc, Constraint Logic Programming, ...
  - Answer Set Programming (ASP)

Why do we need all these syntaxes for expressing the same information?

Isn't it possible to solve multiple types of tasks using the same language?

Spread out over all disciplines of computational logic, there is an enormous expertise about KR and inference.

If only we could bundle what is known about KR and inference in a coherent scientific framework!?

The FO($\cdot$)-KBS project: an integration project

On the logical level: FO($\cdot$)

> Knowledge exists, it can be studied through the methods of formal empirical science

Study "knowledge" by principled development of expressive KR languages:

- Clear informal semantics
- Expressive languages, rich enough so that the information, relevant to solve a problem CAN be represented.
  - (We ignore the "Tractibility/Expressivity" trade-off)
- Classical first-order logic (FO) as foundation, extended where necessary.

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(FO($\cdot$)= family of extensions of FO)

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  - Arithmetic

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  - Coinductive Definitions

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  - Higher Order logic

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  - Coinductive Definitions
  - Modal operators
  - Higher Order logic
  - Causation
  - ...

The FO($\cdot$) language framework

The FO(·)-KBS project: an integration project

- On the inference level:
  - Building solvers for various forms of inference for FO(·)
  - Integrating various solving techniques from various declarative programming paradigms in one Knowledge Base System.

What do I mean with “inference”?

Definition

An inference problem is a computational problem:

- Input: a tuple of objects including a logic theory or formula
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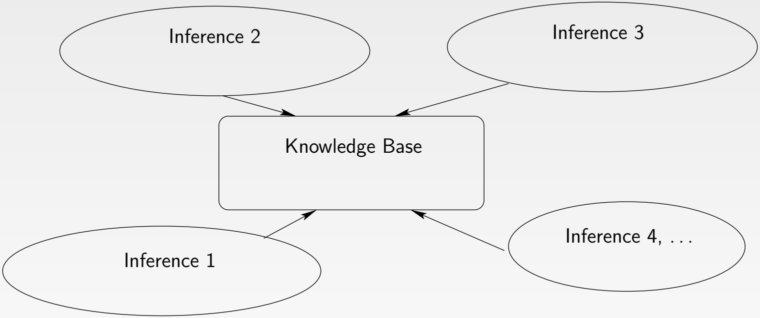
- E.g., Query inference:
  - Input structure $\mathfrak{A}$, set expression $\{\bar{x} : \varphi\}$
  - Output $\{\bar{x} : \varphi\}^{\mathfrak{A}}$

A Knowledge Base System (KBS)



- Manages a declarative Knowledge Base (KB): a theory
- Equiped with different forms of inference

The FO($\cdot$)-KBS project: an integration project

- On the application level:
  - Towards a typology of tasks and computational problems in terms of (the same) logic and inference.
  - Eagerly searching for novel ways of using declarative specifications to solve problems.

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A idealistic view of declarative problem solving in the context of an application

- For a specific problem domain, investigate what knowledge is available, how it could be represented in a natural way, and what sort of inference would solve the problem(s).
- As opposed to: investigate how to encode a computational problem in a given computational logic.

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It is a Work Hypothesis: even failure is interesting.

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- The (revised) KRR hypothesis?
- Ignoring the "Tractibility/Expressivity" trade-off?

- The FO($\cdot$)-KBS project is the long-term research project of the KU Leuven KRR research group.
  - An attempt to set out clear fundamental research goals (this lecture)
  - At the same time, an effort to realize some of this in a practically useful language, system, methodology (next lecture)

IDP, IDP3 and the demos's are available via our webpage
http://krr.bitbucket.org
https://dtai.cs.kuleuven.be/software/idp/
Publications are on line via my webpage
http://people.cs.kuleuven.be/~marc.denecker/