Knowledge Representation and Processing

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Administrative Information

Format

Zoom

- lectures and exercises via zoom
- participants muted by default for simplicity
- interaction strongly encouraged

We don't want to lecture —
we want to have a conversation during which you learn

- let's try out zoom
  - use reactions to say yes no, ask for break etc.
  - feel free to annotate my slides
  - talk in the chat

Recordings

- maybe prerecorded video lectures or recorded zoom meeting
- to be decided along the way

Background

Instructors

- Prof. Dr. Michael Kohlhase
  Professor of Knowledge Representation and Processing
- PD Dr. Florian Rabe same research group

Course

- This course is given for the first time
- Always a little bit of an experiment cutting edge vs. unpolished
- Could become signature course of our research group same name!

Prerequisites

Required

- basic knowledge about formal languages, context-free grammars
  but we'll do a quick revision here

Helpful

- Algorithms and Data Structures — mostly as a contrast to this lecture
- Basic logic — we'll revise it slightly differently here
- all other courses — as examples of how knowledge pervades all of CS

General

- Curiosity — this course is a bit unusual
- Interest in big picture
  this course touches on lots of things from all over CS

Examination and Grading

Suggestion

- grade determined by single exam
- written or oral — depends on number of students
- some acknowledgment for practical exercises

to be finalized next week

Exam-relevant

- anything mentioned in notes
- anything discussed in lectures

neither is a superset of the other!

Materials and Exam-Relevance

Textbook

- does not exist
- normal for research-near specialization courses

Notes

- textbook-style but not as comprehensive
- developed along the way

Slides

- not comprehensive
- used as visual aid, conversation starters

Communication

Open for questions

- open door policy in our offices — if the lockdown ever ends
- always room for questions during lectures
- for personal questions, contact me during/after lecture or by email
- forum at `https://fsi.cs.fau.de/forum/154-Wissensrepraesentation-und-Verarbeitung`

Materials

- official notes and slides as pdf: `https://kwarc.info/teaching/WuV/`
  will be updated from time to time
- watch me prepare the materials: `https://github.com/florian-rabe/Teaching/tree/master/WuV`
  pull requests and issues welcome

Exercises

Learning Goals

- Get acquainted with state of the art of practice
- Try out real tools

Homeworks

- one major project as running example
- homeworks building on each other

build one large knowledge-based system
details on later slides

Overview and Essential Concepts

Representation and Processing

Common pairs of concepts:

Representation	Processing
Static	Dynamic
Situation	Change
Be	Become
Data Structures	Algorithms
Set	Function
State	Transition
Space	Time

Data and Knowledge

2×2 key concepts

Syntax	Data
Semantics	Knowledge

- Data: any object that can be stored in a computer
  Example: $((49.5739143, 11.0264941), "2020-04-21T16:15:00CEST")$
- Syntax: a system of rules that describes which data is **well-formed**
  Example: "a pair of (a pair of two IEEE double precision floating point numbers) and a string encoding of a time stamp"
- Semantics: system of rules that determines the meaning of well-formed data
- Knowledge: combination of some data with its syntax and semantics

Knowledge is Elusive

Representation of key concepts

- Data: using primitive objects
  implemented as bits, bytes, strings, records, arrays, ...
- Syntax: (context-free) grammars, (context-sensitive) type systems
  implemeted as inductive data structures
- Semantics: functions for evaluation, interpretation, of well-formed data
  implemented as recursive algorithms on the syntax
- Knowledge: elusive
  emerges from applying and interacting with the semantics

Semantics as Translation

- Knowledge can be captured by a higher layer of syntax
- Then semantics is translation into syntax

Data syntax	Semantics function	Knowledge syntax
SPARQL query	evaluation	result set
SQL query	evaluation	result table
program	compiler	binary code
program expression	interpreter	result value
logical formula	interpretation in a model	mathematical object
HTML document	rendering	graphics context

Heterogeneity of Data and Knowledge

- Capturing knowledge is difficult
- Many different approaches to semantics
  - fundamental formal and methodological differences
  - often captured in different fields, conferences, courses, languages, tools
- Data formats equally heterogeneous
  - ontologies
  - programs
  - logical proofs
  - databases
  - documents

Challenges of Heterogeneity

Challenges

- collaboration across communities
- translation across languages
- conversion between data formats
- interoperability across tools

Sources of problems

- interoperability across formats/tools major source of
  - complexity
  - bugs
- friction in project team due to differing preferences, expertise
- difficult choice between languages/tools with competing advantages
  - reverting choices difficult, costly
  - maintaining legacy choices increases complexity

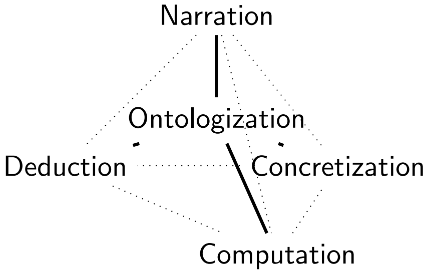
Aspects of Knowledge

- Tetrapod model of knowledge active research by our group
- classifies approaches to knowledge into five aspects

Aspect	KRLs (examples)
ontologization	ontology languages (OWL), description logics (ALC)
concretization	relational databases (SQL, JSON)
computation	programming languages (C)
deduction	logics (HOL)
narration	document languages (HTML, LaTeX)

Relations between the Aspects

Ontology is distinguished: capture the knowledge that the other four aspects share



Complementary Advantages of the Aspects

Aspect	objects	characteristic		
		advantage	joint advantage of the other aspects	application
ded.	formal proofs	correctness	ease of use	verification
comp.	programs	efficiency	well-definedness	execution
concr.	concrete objects	tangibility	abstraction	storage/retrieval
narr.	texts	flexibility	formal semantics	human understanding

Aspect pair	characteristic advantage
ded./comp.	rich meta-theory
narr./conc.	simple languages
ded./narr.	theorems and proofs
comp./conc.	normalization
ded./conc.	decidable well-definedness
comp./narr.	Turing completeness

Structure of the Course

Aspect-independent parts

- general methods that are shared among the aspects
- to be discussed as they come up

Aspects-specific parts

- one part (about 2 weeks) for each aspect
- high-level overview of state of the art
- focus on comparison/evaluation of the aspect-specific results

Structure of the Exercises

One major project

- representative for a project that a CS graduate might be put in charge of
- challenging heterogeneous data and knowledge
- requires integrating/combining different languages, tools

unique opportunity in this course because knowledge is everywhere

Concrete project

- develop a univis-style system for a university
- lots of heterogeneous knowledge
  - course and program descriptions
  - legal texts
  - websites
  - grade tables
  - transcript generation code
- build a completely functional system applying the lessons of the course