19.

Concluding Remarks
CS227
Spring 2011
Outline

- Summary of Key Ideas
- Limitations of Symbolic Representations
- Syllabus for the Final
- Next Steps
Four Clusters of Topics

- Object-oriented representations, description logics, ontologies
- Logic programming, defaults, negation, answer set programs
- Constraint satisfaction, abductive reasoning, qualitative reasoning
- Actions and Planning
Object Oriented Representations

• Key Representation Constructs
  – class, individual, slot and facet
  – subclass-of, instance-of
  – domain, range, cardinality, numeric-minimum, etc

• Key Reasoning Operations
  – Inheritance
  – Default values
Structured Descriptions

• Key Representation Constructs
  – Class, individual, role
  – Concept forming constructors (AND, ALL, EXISTS, FILL…)
  – Role forming constructors (RESTR, …)

• Key Reasoning Operations
  – Subsumption
  – Classification
Key Questions in KR&R Research

- Why restrict the representation language?
- Why not represent anything that needs to be represented using whatever representation language is needed?
- Why not use English as a representation language?
Approach to KR&R System Development

- Given a problem identify a combination of representation and reasoning methods that can solve the problem
- Design a way of combining them into one mechanism
  - Hybrid reasoning
Ontologies

- Everyone uses and has an ontology regardless of whether they know it.
- Ontology provides a representation that is somewhere in between an un-interpreted logical representation and the natural language.
- There are some upper level distinctions and design tools available to help guide the process.
- The ontology construction is an engineering process no different than any other software artifact.
- Ontologies should be evaluated just like any other software system.
Different Flavors of Rule Languages

- Reasoning with Horn Clauses
  - Foundation for logic programming family of languages
- Procedural control of reasoning
  - Negation as Failure - a practical alternative to classical negation
- Production Systems
  - Foundation of expert systems / rule-based systems
- Advanced logics
  - Combining rules with object-oriented and structured representations, higher order logic, modal logic
- Non Monotonic Reasoning
  - Representing default knowledge, answer set programming
Answer Set Programming

- Ability to deal with
  - Disjunction
  - Mixing classical and default negation
  - Formulate many search problems as answer set programs

- Answer set solvers
Expressive Overlaps among KRs

First-Order Logic

Description Logic

Horn Logic Programs

Logic Programs

Non-Monotonic Reasoning

(Procedural Attachments)

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We considered F-Logic and its implementation Flora. Combining formalisms is an active area of research.
Specialized Reasoning Methods

• Constraints, qualitative, abductive
Actions

- Situation calculus as a mechanism to represent change
  - Representation of pre-conditions and effects
  - Successor state axioms
- Reasoning check legality of a sequence of actions and temporal projection
Planning

- Classical planning techniques
  - STRIPS, Graph Plan, Heuristics
- Using knowledge during planning
  - HTN Planning
- CSP, SAT, ASP for planning
Abstraction, Reformulation, Approximation

• Abstraction, reformulation and approximation concepts are pervasive in
  – Conceptual representation of knowledge
  – Problem solving

• (Oversimplified) characterization of ARA concepts
  – abstraction- ignoring some details
  – reformulation- changing the ontology
  – Approximation – concepts that defy complete definitions

• While there is substantial work in using ARA techniques in CSP and planning, little work in knowledge acquisition and explanation generation
Applications and Impact Areas

Computer reading books

Einstein in

Learn to repair a robot on Mars

ENCYCLOPEDIA
On Demand

Military
Logistics

Game
Playing
Practical Skills

• Ontology languages and tools
  – Protégé, OWL
  – Exposure to Semantic Web, RDF
• Rule languages and tools
  – FLORA
• Planning languages and tools
  – PDDL, FF
• (Optionally) Constraint reasoning tools
  – Gecode
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Logic as the Foundation of KR&R

• In this course, we used logic as the foundation for representing knowledge
• There are, however, criticisms of this approach:
  – Deductive reasoning is not enough
  – Deductive reasoning is too expensive
  – Writing down all the knowledge is infeasible
  – Other approaches do it better and cheaper

From Knowledge Representation and Classical Logic by Lifschitz, Morgenstern, and Plaisted in KR&R Handbook
Addressing Criticism of Logic

- Deductive reasoning is not enough
  - Non-monotonic reasoning and defaults
  - Inductive logic programming (See [http://ilp2010.dsi.unifi.it/](http://ilp2010.dsi.unifi.it/))
  - Abductive reasoning
- Deductive reasoning is too expensive
  - Tractable subsets of logic
  - Progress on SAT solver techniques
- Writing down all the knowledge is not feasible
  - Focusing on explicitly written down knowledge
- Other approaches do it better and cheaper
  - Find ways to combine logic with other methods
Probabilistic Representations

- Probabilistic representations were omitted from this course by design, but are covered in-depth in:
  - CS228: Probabilistic Graphical Models
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Syllabus for the Final

• Lecture 11 onwards
  – Answer set programming, Abductive reasoning, constraint satisfaction, representation and reasoning with actions, STRIPS Planning, HTN Planning, CSP for planning, abstraction, reformulation, approximation
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Next Steps

• This course can be followed by
  – CS223: Rational Agency and Intelligent Interaction
  – CS224: Multi-agent systems
  – CS227B: General Game Playing
  – Application of techniques in your respective projects
  – Research opportunities in symbolic representation and reasoning

• Research / Internship opportunities
Emphasis on Content

- “Writing knowledge base content should be front right and center in a KR &R course
  - If I were to have a life threatening event, I will like to be rushed to medical department because they have knowledge, and not to the math department because they have Field medal worthy reasoners”
  - Ed Feigenbaum