

SIE 580: Ontology Engineering Theory and Practice, Spring 2017

School of Computing and Information Science, University of Maine

1 Contact Information

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How to contact me: I'm in my office most other days, so for short questions, feel free to drop by when my door is open. Directly after class is usually the best time to catch me. You can also email or phone me for short questions or to set up an appointment. Email is usually the simplest way to get hold of me even when I'm not in the office.

2 Course Description

Ontologies are explicit specifications of information models and their semantics in formats that are interpretable by humans and computers. The course introduces the philosophical and logical foundations of ontologies and surveys formalisms, modern languages and methods for designing, analyzing and using ontologies. The stages of ontology development from conceptual design to ontology evaluation and verification are studied and practiced using concrete domains.

3 Course Objectives

- Introduce students to a variety of informal methods and logic-based formalisms to analyze and capture the semantics of knowledge;
- Equip students with the basic toolset to develop ontologies using a range formalisms and choosing a formalism suitable for the scope and application of the ontology;
- Enable students to evaluate their own ontologies and ontologies from the literature.

4 Student Learning Outcomes

Upon successful completion of the course, students will be able to

- independently read, comprehend, summarize, and evaluate ontologies as encoded in ontology languages or information systems or as presented in scholarly publications;
- extract the vocabulary relevant for a given domain and represent its key concepts and relations in an organized and precise way using established ontological languages and knowledge representation formalisms;

- apply computational tools to verify ontologies and reason about them, and explain the basic computational techniques they are based on;
- discuss the advantages and the limitations of different languages and formalisms (in particular expressiveness and tractability concerns) for ontology engineering and choose a language suitable for a given problem;
- discuss the different types of ontologies, their uses and limitations.

5 Course Outline

This course gives an introduction and a hands-on experience covering a selection of the most important formalisms, languages, and approaches to capture the semantics of a domain or application of interest in an ontology interpretable by computers and humans. The course consists of a mix of lectures, paper presentations and discussions, and a group project related to a domain/application of your own interest (such as geology, hydrology, building information, genomics, anatomy, e-commerce, health informatics, etc.).

The class meets (tentatively) Monday, Wednesday, and Fridays 2:10-3pm. Lectures and readings will be used to introduce key ideas, formalism, and techniques that you will need to apply to your project. Everyone, not just the assigned presenter, is expected to read the material each week and submit a short summary of the readings and discussion questions. The following outlines topics and respective readings, subject to change:

1. Introduction, examples of ontologies, philosophical foundations (weeks 1 and 2)
 - What are ontologies (week 1) [CJB99]
 - What are concepts, classes, relations, and properties? (week 1) [Jak+13, pp. 1-27]
 - Ontologies as conceptual models: ER & UML diagrams (week 1)
 - Foundational categories & relations (week 2) [Hoe09; Mas+03]
2. Informal Ontologies (week 3)
 - Thesauri/Lexicons: associating form with meaning (example: Wordnet) [Fel06]
 - Taxonomies (example: Snowmed CT) [Bod+07]
 - Taxonomies of relations (example: physical containment relations) [HB13]
3. Good ontology design (week 4)
 - Ontology design methodology [UG96]
 - OntoClean: analyzing ontologies [GW02; GW09]
 - Ontology evaluation [Vra09]
4. Lightweight ontologies for the Semantic Web (week 5)
 - Syntax vs. Semantics
 - Syntactic foundations: XML and URIs
 - Resource Description Framework (RDF) and RDF Schema [McB09]
5. First-order logic ontologies (weeks 6-8)
 - Syntax and semantics of first-order logic (week 6) [Hod01, pp. 9–25]
 - Structures, interpretations, models (week 7) [GOS09]

- Reasoning with first-order logic ontologies (week 7, 8)
 - CNF, skolemization, unification (week 7)
 - Resolution-based theorem proving (week 7) [KV13]
 - Theorem proving with ontologies (week 8) [KG10]
 - SAT-based model finding (week 8) [Gom+08]
 - Common Logic syntax (week 8)
6. The Web Ontology Language (OWL2) (weeks 9 and 10)
- OWL2 syntax and semantics (week 9) [HPS11]
 - Description Logics
 - OWL2 syntax (week 9)
 - Reasoning with OWL2 (week 10)
 - Tableaux-based reasoning [Smu14; TH06]
 - Expressiveness and tractability tradeoff [LB84]
7. Advanced aspects of logic-based ontologies
- Reference, domain, and application ontologies (week 11) [Men03; HSB16]
 - Ontology patterns (week 11) [Fal+13; Hah14]
 - Modules and relationships between ontologies (week 12) [PS09; Grü+14]
 - Ontology Verification (week 13) [GF94; GHK11]
 - Definability (week 14) [Swi98; Hah13]

5.1 Readings

- [Bod+07] Olivier Bodenreider, Barry Smith, Anand Kumar, and Anita Burgunploitingen. “Investigating subsumption in SNOMED CT: An exploration into large description logic-based biomedical terminologies”. In: *Artif. Intell. in Medicine* 39 (2007), pp. 183–195.
- [CJB99] Balakrishnan Chandrasekaran, John R. Josephson, and V. Richard Benjamins. “What are ontologies, and why do we need them?”. In: *IEEE Intelligent Systems* 14.1 (1999), pp. 20–26.
- [Fal+13] Ricardo A. Falbo, Giancarlo Guizzardi, Aldo Gangemi, and Valentina Presutti. “Ontology Patterns: Clarifying Concepts and Terminology”. In: *Workshop on Ontology and Semantic Web Patterns (WOP 2013)*. 2013.
- [Fel06] Christine Fellbaum. “WordNet(s)”. In: *Encyclopedia of Language & Linguistics*. Ed. by Keith Brown. 2nd. Vol. 13. Elsevier, 2006, pp. 665–670.
- [GF94] Michael Grüninger and Mark S. Fox. “The Role of Competency Questions in Enterprise Engineering”. In: *IFIP WG5.7 Workshop on Benchmarking – Theory and Practice, Trondheim, Norway*. 1994.
- [GHK11] Michael Grüninger, Torsten Hahmann, and Megan Katsumi. “Exploiting Modularity for Ontology Verification”. In: *Workshop on Modular Ontologies (WoMo 2011)*. IOS Press, 2011.

- [Gom+08] Carla P. Gomes, Henry Kautz, Ashish Sabharwal, and Bart Selman. “Satisfiability Solvers”. In: *Handbook of Knowledge Representation*. Elsevier, 2008, pp. 89–134.
- [GOS09] Nicola Guarino, Daniel Oberle, and Steffen Staab. “What is an Ontology”. In: *Handbook on Ontologies*. Springer, 2009, pp. 1–17.
- [Grü+14] Michael Grüninger, Carmen Chui, Torsten Hahmann, and Megan Katsumi. “A Side-ways Look at Upper Ontologies”. In: *Formal Ontology in Inf. Systems (FOIS-14)*. IOS Press, 2014.
- [GW02] Nicola Guarino and Christopher A. Welty. “Evaluating ontological decisions with OntoClean”. In: *Comm. ACM* 45.2 (2002), pp. 61–65.
- [GW09] Nicola Guarino and Christopher A. Welty. “An overview of OntoClean”. In: *Handbook on Ontologies*. Springer, 2009, pp. 201–220.
- [Hah13] Torsten Hahmann. “A Reconciliation of Logical Representations of Space: from Multi-dimensional Mereotopology to Geometry, Chapter 2 “Methodology: theory extensions and interpretations””. PhD thesis. Univ. of Toronto, Dept. of Comp. Science, 2013.
- [Hah14] Torsten Hahmann. “Ontology Repositories: A Treasure Trove for Content Ontology Design Patterns”. In: *Proc. of the Workshop on Modular Ontologies (WoMO 2014)*. 2014.
- [HB13] Torsten Hahmann and Boyan Brodaric. “Kinds of full physical containment”. In: *Spatial Inf. Theory (COSIT-13)*. Springer, 2013.
- [Hod01] Wilfrid Hodges. “Classical logic I: first order logic”. In: *The Blackwell Guide to Philosophical Logic*. Blackwell, 2001, pp. 9–32.
- [Hoe09] Rinke Hoekstra. “Ontologies”. In: *Ontology Representation*. IOS Press, 2009. Chap. 4.
- [HPS11] Ian Horrocks and Peter F. Patel-Schneider. “KR and reasoning on the semantic web: OWL”. In: *Handbook of Semantic Web Technologies*. Springer, 2011, pp. 365–398.
- [HSB16] Torsten Hahmann, Shirly Stephen, and Boyan Brodaric. “Semantically Refining the Groundwater Markup Language (GWML2) with the Help of a Reference Ontology (Short Paper)”. In: *Geographic Information Science (GIScience 2016), Montreal, Sept. 27-30, 2016*. 2016r.
- [Jak+13] Grega Jakus, Veljko Milutinović, Sanida Omerović, and Sašo Tomažič. *Concepts, Ontologies, and Knowledge Representation*. Springer, 2013.
- [KG10] Megan Katsumi and Michael Grüninger. “Theorem proving in the ontology lifecycle”. In: *Knowledge Engineering and Ontology Design (KEOD 2010)*. 2010.
- [KV13] Laura Kovács and Andrei Voronkov. “First-order theorem proving and Vampire”. In: *Computer Aided Verification (CAV 2013)*. 2013.
- [LB84] Hector Levesque and Ronald Brachman. “A Fundamental Tradeoff in Knowledge Representation and Reasoning (Revised Version)”. In: *Canadian Society for Computational Studies of Intelligence (CSCSI)*. 1984, pp. 141–152.
- [Mas+03] Claudio Masolo et al. *Wonderweb deliverable D17 - The WonderWeb Library of Foundational Ontologies Preliminary Report*. Tech. rep. National Research Council - Institute of Cognitive Sci. and Technology, Trento, 2003.
- [McB09] Brian McBride. “The Resource Description Framework (RDF) and its Vocabulary Description Language RDFS”. In: *Handbook on Ontologies*. Springer, 2009, pp. 51–65.

- [Men03] Christopher Menzel. “Reference Ontologies – Application Ontologies: Either/Or or Both/And?” In: *Workshop on Reference Ontologies and Application Ontologies at KI-03*. 2003.
- [PS09] Christine Parent and Stefano Spaccapietra. “An overview of modularity”. In: *Intern. Workshop on Modular Ontologies (WoMO 2009)*. Ed. by Heiner Stuckenschmidt, Christine Parent, and Stefano Spaccapietra. Vol. LNCS 5445. 2009, pp. 5–23.
- [Smu14] Raymond M. Smullyan. “A Beginner’s Guide to Mathematical Logic”. In: 2014. Chap. Propositional Tableaux.
- [Swi98] Zeno Swijtink. “Beth’s Theorem and Craig’s Theorem”. In: *Routledge Encyclopedia of Philosophy*. Ed. by Edward Craig. Taylor and Francis, 1998.
- [TH06] Dmitry Tsarkov and Ian Horrocks. “FaCT++ description logic reasoner: System description”. In: *Intern. Joint Conf. on Automated Reasoning (IJCAR)*. 2006.
- [UG96] Michael Uschold and Michael Gruninger. “Ontologies: Principles, Methods and Applications”. In: *Knowledge Eng. Review* 11.2 (1996).
- [Vra09] Denny Vrandečić. “Ontology Evaluation”. In: *Handbook on ontologies*. Springer, 2009, pp. 293–313.

5.2 Additional Material

- Semantic Web Primer Tutorials on Graph Data, RDF, XML, RDFS, OWL: <http://www.linkeddatatools.com/semantic-web-basics>
- OWL2 Primer: <https://www.w3.org/TR/owl2-primer/>

5.3 Prerequisites

Some familiarity with propositional and predicate (first-order) logic (as taught in SIE 505 or an undergraduate course in discrete mathematics) is strongly recommended. No previous programming experience or experience with ontology design is necessary.

6 Expectations and Assessments

I understand that everybody’s background will be quite diverse, many of you having no previous experience with logic-based ontologies. While no specific technical background is required, I expect a willingness to work your way through fairly technical and formal material. To properly understand the material, you may have to reread it multiple times or to consult additional sources. We will go over basics fairly quickly, so you may have to do additional readings on your own to keep up with the pace of the course. Of course, I’m willing to help and guide you in this process.

6.1 Grading

Your grade for the course will be calculated from the following components:

- 10% weekly summaries
- 10% weekly discussion questions and active participation in the discussion
- 20% individual paper presentations and discussion lead (10% each)
- 20% group presentation and discussion lead

- 40% Group project on developing/refining an ontology
 - Part 1: Conceptual Model (due 2/26)
 - Part 2: FOL ontology and reasoning (due 3/26)
 - Part 3: OWL ontology and reasoning (due 4/16)
 - Part 4: Review and analysis of a related ontology, written up as a 4-5 page paper (due finals week)

6.2 Weekly summaries

Two days before class, you are expected to submit a short summary (no more than half a page) of the readings. This is to prepare for active participation in the discussion, ensuring that you are familiar with the topic and key ideas. While you are not expected to understand every detail, you are expected to read it to sufficient details so that you can contribute to and will benefit from the class discussion.

6.3 Discussion questions and participation

Together with your summary, you are asked to submit **at least** two questions to be discussed in class. These can be understanding questions about the assigned readings but should include at least one deeper question that sparks discussion.

Your attendance and active participation in class discussions also count towards this portion of your grade. If you are absent due to illness or another important reason, please email me immediately prior to or after your absence.

6.4 Student Presentations

Individual presentations Each student will present an overview of two readings throughout the term. The presentation should be around 30min. It should not be a mere summary of the reading, but focus on the key concepts and techniques presented therein. Where appropriate, the presentation should involve going through an example or practical problem with the class. You must share and discuss an outline of your presentation with the instructor the week before your scheduled presentation.

Group presentations At the end of the term, everyone will work through and present one of the advanced topics as a group (typically 2 students per group). Each topic is discussed in two articles, with one being more introductory and one more technical. You are expected to consult additional literature as needed. You are expected to structure and present the key ideas in class with examples and lead the subsequent class discussion.

6.5 Group projects

For the project, you are expected to work in teams (2-3 students) on a domain of your own choice (e.g., related to your research) and try out the ontology development languages and techniques in that topic. Be careful to choose a very small domain; the intention is not to try to build a large ontology (which cannot be accomplished in the given time), but rather to build a small snippet of an ontology well.

You will need to start working on the project at the beginning the term and present intermediate milestones briefly (5min) in class.

Table 1: Outline of topics and readings for student presentations.

| week | topic | reading |
|-----------|--|-----------------|
| 3 (2/6) | WordNet | [Fel06] |
| | SnoMed CT | [Bod+07] |
| 4 (2/13) | Ontology Development Methodology | [UG96] |
| | OntoClean | [GW02; GW09] |
| | Ontology Evaluation | [Vra09] |
| 7 (3/20) | Logic-based ontologies | [GOS09] |
| | Resolution-Based Theorem Proving | [KV13] |
| 8 (3/27) | Theorem Proving with Ontologies | [KG10] |
| | SAT Solvers | [Gom+08] |
| 10 (4/10) | Tableaux and Tableaux for OWL Reasoning | [Smu14; TH06] |
| | Expressivity and Tractability Tradeoff | [LB84] |
| 11 (4/17) | Types of ontologies | [Men03; HSB16] |
| | Ontology patterns (group presentation) | [Fal+13; Hah14] |
| 12 (4/14) | Ontology modules (group presentation) | [PS09; Grü+14] |
| 13 (4/31) | Ontology verification (group presentation) | [GF94; GHK11] |

7 Academic Honesty

Academic honesty is very important. It is dishonest to cheat on exams, to copy term papers, to submit papers written by another person, to fake experimental results, or to copy or reword parts of books or articles into your own papers without appropriately citing the source. Students committing or aiding in any of these violations may be given failing grades for an assignment or for an entire course, at the discretion of the instructor. In addition to any academic action taken by an instructor, these violations are also subject to action under the University of Maine Student Conduct Code. The maximum possible sanction under the student conduct code is dismissal from the University.

Plagiarism—one form of academic dishonesty—is the handing in of work not substantially the student’s own. It is usually done without reference, but is unacceptable even in the guise of acknowledged copying. It is not cheating, however, to discuss ideas and approaches to a problem, nor is it cheating to seek or accept help. Indeed, collaboration is encouraged as a useful part of the learning experience in this course. Nevertheless, good judgment must be used, and students are expected to present the results of their own thinking and writing.

8 Students with disabilities

If you have a disability for which you may be requesting an accommodation, please contact Disabilities Services, 121 East Annex, 581-2319, as early as possible in the term.

9 Extended disruption

In the event of an extended disruption of normal classroom activities, the format for this course may be modified to enable its completion within its programmed time frame. In that event, you will be provided an addendum to the syllabus that will supersede this version.

10 UMaine's Sexual Discrimination Reporting

The University of Maine is committed to making campus a safe place for students. Because of this commitment, if you tell a teacher about an experience of sexual assault, sexual harassment, stalking, relationship abuse (dating violence and domestic violence), sexual misconduct or any form of gender discrimination involving members of the campus, your teacher is required to report this information to the campus Office of Sexual Assault & Violence Prevention or the Office of Equal Opportunity.

If you want to talk in confidence to someone about an experience of sexual discrimination, please contact these resources:

- For confidential resources on campus: Counseling Center: 207-581-1392 or Cutler Health Center: 207-581-4000.
- For confidential resources off campus: Rape Response Services: 1-800-310-0000 or Spruce Run: 1-800-863-9909.
- The following resources on campus can offer support but may have to report the incident to others who can help: Office of Sexual Assault & Violence Prevention: 207-581-1406, Office of Community Standards: 207-581-1409, University of Maine Police: 207-581-4040 or 911.

See the OSAVP website for a complete list of services at <http://www.umaine.edu/osavp/>