MIE1501F: Knowledge Modelling and Management: Semantic Web and Linked Data
Revised: 4 September 2021

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http://www.eil.utoronto.ca/members/msf/

Description:
Knowledge Modeling and Management focuses on the representation and use of information in the context of the web. In particular, it focuses on AI Knowledge Representation (aka Ontology). The first part of the course focuses the theory of knowledge representation and ontologies. Followed by methods of engineering ontologies. The second part focuses on how ontologies are implemented on the Semantic Web, including Linked Data, SPARQL, OWL (Web Ontology Language) and the Python RDFLib library. The third part focuses on the emergence of generic ontologies for concepts such as time, geospatial, measurement, provenance, trust, etc. The final part focuses on applications such as Smart Cities and Enterprise Modelling.

Prerequisites:
1. Undergraduate programming course
2. Undergraduate data structures and database course, or equivalent
3. Experience in Python programming

Background References:
- Antoniou, G., Groth, P., van Harmelen, F., and Hoekstra, R., (2012), *A Semantic Web Primer*, MIT Press, 3rd Edition
- Allemang, D., and Hendler, J., (2011), *Semantic Web for the Working Ontologist*, 2nd Edition, Morgan Kaufmann.

Week	Topics	Materiel
Theory		
1	• Smart Cities • Knowledge Representation • Interoperability • Intro to Ontologies	• Slides ○ 1.1 Smart Cities http://ontology.eil.utoronto.ca/MIE1501/syllabus/W1/1.1SmartCities.pdf ○ 1.2 Interoperability http://ontology.eil.utoronto.ca/MIE1501/syllabus/W1/1.2Interoperability.pdf ○ 1.3. Knowledge Types http://ontology.eil.utoronto.ca/MIE1501/syllabus/W1/1.3KnowledgeTypes.pdf ○ 1.4 Ontology Introduction

		http://ontology.eil.utoronto.ca/MIE1501/syllabus/W1/1.4Ontology.pdf ○ 1.5 Reasoning Introduction http://ontology.eil.utoronto.ca/MIE1501/syllabus/W1/1.5Reasoning.pdf • Recordings – must have UofT mymedia account ○ Week 1 lecture recording https://play.library.utoronto.ca/watch/4cbca02fc8bb07d2c717e808fe0a66cd • Readings ○ Davis, R., Shrobe, H., and Szolovits, P., (1993), "What is a Knowledge Representation", *AI Magazine*, Spring Issue, pp. 17-33. https://ojs.aaai.org/index.php/aimagazine/article/download/1029/947
2	Description Logic	• Slides ○ 2.1 Definitions http://ontology.eil.utoronto.ca/MIE1501/syllabus/W2/2.1Definitions.pdf ○ 2.2 Description Logic T Box http://ontology.eil.utoronto.ca/MIE1501/syllabus/W2/2.2DLTBox.pdf ○ 2.3 Description Logic T Box Examples http://ontology.eil.utoronto.ca/MIE1501/syllabus/W2/2.3DLTBoxExamples.pdf ○ 2.4 Description Logic A Box http://ontology.eil.utoronto.ca/MIE1501/syllabus/W2/2.4DLABox.pdf • Recordings – must have UofT mymedia account ○ 2.1-2.4 Description Logic – watch up to 2:42:00 https://play.library.utoronto.ca/watch/88c8d12932f28b97497363fdc0121f4a • Readings ○ M. Krötzsch, F. Simancík, and I. Horrocks, "A Description Logic Primer," CoRR, abs/1201.4089, 2012; http://korrekt.org/page/A_Description_Logic_Primer ○ Fox, M.S., and Forde, A., (2020), "Towards a City Data Ontology: A Design Pattern for City Resident". http://ontology.eil.utoronto.ca/MIE1501/syllabus/W2/Fox-WOP2020 v2.pdf
Engineering and Evaluation		
3	• Ontology Engineering • Ontology Evaluation	• Slides • 3.1 Ontology Engineering http://ontology.eil.utoronto.ca/MIE1501/syllabus/W3/3.1-Ontology-Engineering.pdf • 3.2 Building Ontologies http://ontology.eil.utoronto.ca/MIE1501/syllabus/W3/3.2-Building-Ont.pdf • 3.3 Documenting Ontologies

		http://ontology.eil.utoronto.ca/MIE1501/syllabus/W3/3.3-Documenting-Ont.pdf • 3.4 Evaluating Ontologies http://ontology.eil.utoronto.ca/MIE1501/syllabus/W3/3.4-Evaluating-Ontologies.pdf • 3.5 Building Energy Ontology Case Study http://ontology.eil.utoronto.ca/MIE1501/syllabus/W3/3.5-BEM-Case.pdf • Recordings – must have UofT mymedia account • 3.1-3.3 Ontology Eng, Building, Documentation https://play.library.utoronto.ca/watch/aa31c240aead0e16f9e893492f104dec • 3.4 Ontology Evaluation https://play.library.utoronto.ca/watch/c89b9e5e283c208ed1e0f3966d98b465 • Readings • Noy, N.F., and McGuinness, D.L., (2001), "Ontology Development 101: A Guide to Creating Your First Ontology", Stanford Knowledge Systems Laboratory Technical Report KSL-01-05 and Stanford Medical Informatics Technical Report SMI-2001-0880. https://corais.org/sites/default/files/ontology_development_101_aguide_to_creating_your_first_ontology.pdf • [Optional] Grüninger, M., and Fox, M.S., (1995), "Methodology for the Design and Evaluation of Ontologies", *Proceedings of the Workshop on Basic Ontological Issues in Knowledge Sharing*, IJCAI-95, Montreal. http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=C5AB88B4C2918C935CFF6B71CEBEEB8E?doi=10.1.1.44.8723&rep=rep1&type=pdf • DeBellis, M., (2020), "A Practical Guide to Building OWL Ontologies Using Protégé 5.5 and Plugins". https://tinyurl.com/NewPizzaTutorialV1 • [Optional] Stevens, R., Stevens, M., Matentzoglu, N., and Jupp, Simon, (2013), "Manchester Family History Advanced OWL Tutorial", University of Manchester, http://owl.cs.manchester.ac.uk/tutorials/fhkbtutorial/ • Hitzler, P., Krötzsch, M., Parsia, B., Patel-Schneider, P. F., & Rudolph, S. (2009). OWL 2 web ontology language primer. *W3C recommendation*, *27*(1), 123. https://www.w3.org/TR/2009/PR-owl2-primer-20090922/all.pdf • Fox, M.S., (2015), "Guidelines for Creating and Publishing Ontologies". http://ontology.eil.utoronto.ca/MIE1501/syllabus/W3/Guidelines-for-Creating-Ontologies.pdf • M. Poveda-Villalón, M.C. Suárez-Figueroa, A. Gómez-Pérez. Validating ontologies with OOPS!. *18th International Conference on Knowledge Engineering and*

		Knowledge Management (EKAW2012), pp. 8–12, October 2012, Galway, Ireland. https://core.ac.uk/download/pdf/148662798.pdf • Tartir, S., Arpinar, B., Moore, M., Sheth, A.P., Aleman-Meza, B., (2005), "OntoQA: Metric-based ontology quality analysis", *IEEE Workshop on Knowledge Acquisition from Distributed, Autonomous, Semantically Heterogeneous Data and Knowledge Sources* (Vol. 9). https://corescholar.libraries.wright.edu/cgi/viewcontent.cgi?article=2036&context=knoesis • Fox, M.S., Hussain, B., Le, M., and Rosu, D., (2018), "An Ontology for Smart Building Energy Management", Technical Report, Enterprise Integration Lab., University of Toronto. http://ontology.eil.utoronto.ca/MIE1501/syllabus/W3/BEM-Ontology-27oct2019.pdf
Technology		
4	• Linked Data • Turtle • Fuseki	• Slides ○ 4.1 Linked Data http://ontology.eil.utoronto.ca/MIE1501/syllabus/W4/4.1-LD.pdf ○ 4.2 Turtle http://ontology.eil.utoronto.ca/MIE1501/syllabus/W4/4.2-Turtle.pdf ○ 4.3 Fuseki Endpoint http://ontology.eil.utoronto.ca/MIE1501/syllabus/W4/4.3-Fuseki.pdf • Recordings – must have UofT mymedia account ○ 4.1 Linked Data https://play.library.utoronto.ca/watch/a240a0e242842f5798465d5c639c444c ○ 4.2 Turtle https://play.library.utoronto.ca/watch/6c0cb7234cd6c51fd1cbb19ec267ea35 ○ 4.3 Fuseki Endpoint https://play.library.utoronto.ca/watch/ac56b413b1addec14da7747a69f8afd7 • Readings • Poblet, M., Casanovas, P., & Rodríguez-Doncel, V. (2019). Introduction to Linked Data. In *Linked Democracy* (pp. 1-25). Springer, Cham. https://link.springer.com/chapter/10.1007/978-3-030-13363-4_1 • Beckett, D., Berners-Lee, T., Prud'hommeaux, E., and Carothers, G., (2012), "Turtle: Terse RDF Triple Language", http://www.w3.org/TR/turtle/ • Lehmann, J., Isele, R., Jakob, M., Jentzsch, A., Kontokostas, D., Mendes, P. N., ... & Bizer, C. (2015). DBpedia–a large-scale, multilingual knowledge base extracted from

		Wikipedia. *Semantic Web*, *6*(2), 167-195. https://www.researchgate.net/profile/Christian-Bizer/publication/259828897_DBpedia_-_A_Large-scale_Multilingual_Knowledge_Base_Extracted_from_Wikipedia/links/0deec52e78a6e95b73000000/DBpedia-A-Large-scale-Multilingual-Knowledge-Base-Extracted-from-Wikipedia.pdf • Vrandečić, D., Krötzsch,M., (2014), "Wikidata: A free collaborative knowledgebase", *Communications of the ACM*, Vol. 57, No. 10. http://ontology.eil.utoronto.ca/MIE1501/syllabus/W4/vrandecic-acm14.pdf
5	• Queries and Endpoints • SPARQL	• Slides ○ 5.1 SPARQL Basics http://ontology.eil.utoronto.ca/MIE1501/syllabus/W5/5.1-SPARQL-Basics.pdf ○ 5.2 SPARQL Constraints http://ontology.eil.utoronto.ca/MIE1501/syllabus/W5/5.2-SPARQL-Constraints.pdf ○ 5.3 SPARQL Aggregates http://ontology.eil.utoronto.ca/MIE1501/syllabus/W5/5.3-SPARQL-Aggregates.pdf ○ 5.4 SPARQL Graphs http://ontology.eil.utoronto.ca/MIE1501/syllabus/W5/5.4-SPARQL-Graphs.pdf ○ 5.5 SPARQL Query Forms http://ontology.eil.utoronto.ca/MIE1501/syllabus/W5/5.5-SPARQL-Query-Forms.pdf ○ 5.6 SPARQL Fuseki http://ontology.eil.utoronto.ca/MIE1501/syllabus/W5/5.6-SPARQL-Fuseki.pdf • Recordings – must have UofT mymedia account ○ 5.1 SPARQL Basics https://play.library.utoronto.ca/watch/db942db58cc0f53cb30f1bccc54b8a76 ○ 5.2 SPARQL Constraints https://play.library.utoronto.ca/watch/553ebba7205cf09598e5cf74707f2431 ○ 5.3 SPARQL Aggregates https://play.library.utoronto.ca/watch/60c238ae1965f7fc20eba05abb8f53f9 ○ 5.4 SPARQL Graphs https://play.library.utoronto.ca/watch/db461cd089e6cefa369dac0a80d0e330 ○ 5.5 SPARQL Query Forms https://play.library.utoronto.ca/watch/0ee33ec7e5aeb4066f1a18e2b42c3de1 ○ 5.6 SPARQL Fuseki https://play.library.utoronto.ca/watch/672a0c97a31c084846c7415ffa02cbcf • Readings

		○ Prud'hommeaux, E., and Seaborne, A., (2008), "SPARQL Query Language for RDF", http://www.w3.org/TR/rdf-sparql-query/ • Software ○ SPARQL Validator: http://sparql.org/query-validator.html
	Python RDFLIB	• Slides ○ 6.1 RDFLib Introduction http://ontology.eil.utoronto.ca/MIE1501/syllabus/W6/6.1-RDFLib-Intro.pdf ○ 6.2 RDFLib DB http://ontology.eil.utoronto.ca/MIE1501/syllabus/W6/6.2-RDFLib-DB.pdf ○ 6.3 RDFLib SPARQL http://ontology.eil.utoronto.ca/MIE1501/syllabus/W6/6.3-RDFLib-SPARQL.pdf ○ 6.4 RDFLib SHACL http://ontology.eil.utoronto.ca/MIE1501/syllabus/W6/6.4-SHACL.pdf • Recordings – must have UofT mymedia account ○ 6.1 RDFLib Introduction https://play.library.utoronto.ca/watch/f980e86c8f5021ed5ace9d8abdd05664 ○ 6.2 RDFLib DB https://play.library.utoronto.ca/watch/1df8ea750821339d41415f51b7f7eac8 ○ 6.3 RDFLib SPARQL https://play.library.utoronto.ca/watch/c30f4405769da7d6da07210bdd069e44 • Readings ○ RDFLib Team, "rdflib Documentation, Release 4.2.2", https://media.readthedocs.org/pdf/rdflib/4.2.2/rdflib.pdf
Generic Ontologies		
7	Foundation Ontologies 1 • Time • Constrained time • Change • Spatial	• Slides ○ 7.1 ISO/IEC 5087 Introduction http://ontology.eil.utoronto.ca/MIE1501/syllabus/W7/7.1-5087-Intro.pdf ○ 7.2 Time Ontology http://ontology.eil.utoronto.ca/MIE1501/syllabus/W7/7.2-Time.pdf ○ 7.3 Constrained Time Ontology http://ontology.eil.utoronto.ca/MIE1501/syllabus/W7/7.3-Constrained-Time.pdf ○ 7.4 Change Ontology http://ontology.eil.utoronto.ca/MIE1501/syllabus/W7/7.4-Change.pdf ○ 7.5 Spatial Ontology http://ontology.eil.utoronto.ca/MIE1501/syllabus/W7/7.5-Spatial.pdf

		○ 7.6 Wright Case Study http://ontology.eil.utoronto.ca/MIE1501/syllabus/W7/7.6-Wright-Case-Study.pdf • Recordings – must have UofT mymedia account ○ 7.1 ISO/IEC 5087 Introduction; 7.2 Time Ontology; 7.4 Change Ontology – watch until 2:17:10 https://play.library.utoronto.ca/watch/4b246111fda9c54c8f4428f4a3d1f943 ○ 7.3 Constrained Time Ontology https://play.library.utoronto.ca/watch/d04534c0fa9ce21e1cfab8f8c5315bc4 ○ 7.5 Spatial Ontology https://play.library.utoronto.ca/watch/56a21810ac2713e3d95de59e66885e85 ○ 7.6 Wright Case Study https://play.library.utoronto.ca/watch/fa0ae416d317feb2cc019d5304966898 • Readings ○ Allen, J.F., (1983), "Maintaining Knowledge about Temporal Intervals", *Communication of the Association of Computing Machinery*, Vol. 26, No. 11, pp. 832-843. https://dl.acm.org/doi/pdf/10.1145/182.358434?casa_token=Hzz52l1HZ0EAAAAA:yWIkTqYKo4-C8ODsKjmgS8pPPaGJee03tqRZtwBUmFQRN-Wo--pa5wkNuBB2GJh9cSwaQBtJCgY ○ Pan, F., and Hobbs, J.R., (2004), "Time in OWL-S", In *Proceedings of AAAI-04 Spring Symposium on Semantic Web Services*, Stanford University, California, 2004. https://www.aaai.org/Papers/Symposia/Spring/2004/SS-04-06/SS04-06-005.pdf ○ Janowicz, K., Scheider, S., Pehle, T., and Hart, G., (2012), "Geospatial Semantics and Linked Spatiotemproal Data – Past, Present and Future, *Semantic Web,* Vol. 3, No. 4, pp. 321-332. https://content.iospress.com/download/semantic-web/sw077?id=semantic-web%2Fsw077 ○ Battle, R. and Kolas, D., (2012), "GeoSPARQL: Enabling a Geospatial Semantic Web", *Semantic Web Journal*, Vol. 3, No. 4, pp. 355-370. http://semantic-web-journal.org/sites/default/files/swj176_1.pdf ○ [Optional] Atemezing, G.A., and Troncy, R., (2012), "Comparing Vocabularies for Representing Geographical Features and Geometry"*, 11th International Semantic Web Conference, Terra Cognita Workshop*, Volume 901, Boston, USA. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.416.1064&rep=rep1&type=pdf#page=11

		○ Baykan, C.A., and Fox, M.S., (1997), "Spatial Synthesis by Disjunctive Constraint Satisfaction", *Artificial Intelligence for Engineering, Design, Analysis and Manufacturing*, Vol. 11, No. 4, pp. 245-262. https://www.cambridge.org/core/services/aop-cambridge-core/content/view/B302538003079041B1B6E4E46AA5850F/S0890060400003206a.pdf/spatial-synthesis-by-disjunctive-constraint-satisfaction.pdf?casa_token=4m9Y2YjmvEcAAAAA:KHj1S9Xae4YeqobU9A6thpRVZCLS-uPjXS_2sKA9n5psCuzX1yjMcXpxbYQl6nNlIEfHKM4
8	Foundation Ontologies 2 • Activity • Resource • Organization • Cost	• Slides ○ 8.1 Activity Ontology http://ontology.eil.utoronto.ca/MIE1501/syllabus/W8/8.1-Activity.pdf ○ 8.2 Resource Ontology http://ontology.eil.utoronto.ca/MIE1501/syllabus/W8/8.2-Resource.pdf ○ 8.3 Organization Ontology 1 http://ontology.eil.utoronto.ca/MIE1501/syllabus/W8/8.3-Organization-1.pdf ○ 8.4 Organization Ontology 2 http://ontology.eil.utoronto.ca/MIE1501/syllabus/W8/8.4-Organization-2.pdf ○ 8.5 Cost Ontology http://ontology.eil.utoronto.ca/MIE1501/syllabus/W8/8.5-Cost-Modelling.pdf • Recordings – must have UofT mymedia account ○ 8.1 Activity Ontology – (0 – 31:00) https://play.library.utoronto.ca/watch/5bf916baf0093edacd669f54522fe4d3 ○ 8.2 Resource Ontology (18:47 to end) https://play.library.utoronto.ca/watch/ca5f9f275e0f2a724e8699e2b1178e92 ○ 8.3 Organization Ontology 1 (32:25 – 57:10) https://play.library.utoronto.ca/watch/52431201af7e354849d2671eb3cd717e ○ 8.4 Organization Ontology 2 https://play.library.utoronto.ca/watch/6fd418de5e708416d998542bf5526b49 ○ 8.5 Cost Ontology https://play.library.utoronto.ca/watch/582b22898f100e84cc3ccb3bf99ee799 • Readings ○ Fadel, F. G., Fox, M.S., and Gruninger, M. (1994) "A Resource Ontology for Enterprise Modelling", *Proceedings of the Third Industrial Engineering Research Conference*, Institute of Industrial Engineers, pp. 455-460. http://www.eil.toronto.edu/wp-content/uploads/enterprise-modelling/papers/fadel-ierc94.pdf

		○ Reynolds, D., (2014). "The organization ontology: W3C Recommendation 16 January 2014", World Wide Web Consortium. https://www.w3.org/TR/vocab-org ○ Fox, M.S., Barbuceanu, M., Gruninger, M., and Lin, J., (1998), "An Organisation Ontology for Enterprise Modeling", In *Simulating Organizations: Computational Models of Institutions and Groups*, M. Prietula, K. Carley & L. Gasser (Eds), Menlo Park CA: AAAI/MIT Press, pp. 131-152. http://www.eil.utoronto.ca/enterprise-modelling/papers/org-prietula-23aug97.pdf ○ Kim, H.M., Fox, M.S., and Gruninger, M., (1999), "An ontology for quality management – enabling quality problem identification and tracing", *BT Technology Journal*, Vol. 17, No. 4, pp. 131-140. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.454.6433&rep=rep1&type=pdf ○ Tham, D., Fox, M.S., and Gruninger, M., (1994), "A Cost Ontology for Enterprise Modelling", *Proceedings of the Third Workshop on Enabling Technologies – Infrastructures for Collaborative Enterprises* , West Virginia University. https://ieeexplore.ieee.org/iel2/970/7827/00330502.pdf?casa_token=vTAeEyPLctsAAAAA:p17LZfxCGjoxbcMDPEarIZieSeGz3q3uUHtAlnvnknxmw_nhI7UGOpami7HGNIzLzfQm6B8
9	Meta Data Ontologies • Measurement • Provenance • Validity • Trust	• Slides ○ 9.1 Measurement Ontology http://ontology.eil.utoronto.ca/MIE1501/syllabus/W9/9.1-Measurement.pdf ○ 9.2 Provenance Ontology http://ontology.eil.utoronto.ca/MIE1501/syllabus/W9/9.2-Provenance.pdf ○ 9.3 Validity Ontology http://ontology.eil.utoronto.ca/MIE1501/syllabus/W9/9.3-Validity.pdf ○ 9.4 Trust Ontology http://ontology.eil.utoronto.ca/MIE1501/syllabus/W9/9.4-Trust.pdf • Recordings – must have UofT mymedia account ○ 9.1 Measurement Ontology (2:10:00 – 2:38:41) https://play.library.utoronto.ca/watch/38bf0732a95816d48fd5cf66ad65b942 ○ 9.2 Provenance Ontology (2:38:50 – 2:52:30) https://play.library.utoronto.ca/watch/38bf0732a95816d48fd5cf66ad65b942 ○ 9.3 Validity Ontology https://play.library.utoronto.ca/watch/e70f01083aec7fabca9d3373dab123ad ○ 9.4 Trust Ontology

		https://play.library.utoronto.ca/watch/44aaa57e777df2134419ce11c864ae42 • Readings ○ Rijgersberg, H., van Assem, M., & Top, J. (2013). Ontology of units of measure and related concepts. *Semantic Web*, *4*(1), 3-13. http://semantic-web-journal.org/sites/default/files/swj177_3.pdf ○ Fox, M.S., and Huang, J., (2005), "Knowledge provenance in enterprise information", *International Journal of Production Research*, vol. 43, no. 20, pp. 4471–4492. https://www.tandfonline.com/doi/pdf/10.1080/00207540500142415?casa_token=o4YcqBRKPmoAAAAA:eDLOr4dffpzBfw5xY74RxQmerUVe4A8YKfQ5_7NUMtAp-o9OX5aLtQ7UCQXJm-FLO6GWlRzVh-c ○ Belhajjame, K., et al., (2012), "PROV Model Primer", http://www.w3.org/TR/prov-primer ○ Huang, J., and Fox, M.S., (2006), "An Ontology of Trust – Formal Semantics and Transitivity," *Proceedings of the International Conference on Electronic Commerce*, pp. 259-270. https://dl.acm.org/doi/pdf/10.1145/1151454.1151499?casa_token=wE-2KAj3MJ8AAAAA:kNA9AxuSx81YhV6BU28R5nZFJt4fyCFMROd90mY7w_pNrHzZRduYDBTkyCVIOJsJoLnFlumcugc
Application Ontologies		
10	City Indicators	• Slides ○ 10.1 Metrics http://ontology.eil.utoronto.ca/MIE1501/syllabus/W10/10.1-Metrics-Short.pdf ○ 10.2 PolisGnosis http://ontology.eil.utoronto.ca/MIE1501/syllabus/W10/10.2-PolisGnosis.pdf ○ 10.3 City Indicator Ontology http://ontology.eil.utoronto.ca/MIE1501/syllabus/W10/10.3-City-Indicator-Ontology.pdf ○ 10.4 Consistency Analysis http://ontology.eil.utoronto.ca/MIE1501/syllabus/W10/10.4-Consistency-Analysis.pdf • Recordings – must have UofT mymedia account ○ 10.1 Metrics https://play.library.utoronto.ca/watch/9763648ed6325e7802ef8165565fb8b7 ○ 10.2 PolisGnosis https://play.library.utoronto.ca/watch/661e7d1c753387875cdf07dfeeeba2b6 ○ 10.3 City Indicator Ontology

		https://play.library.utoronto.ca/watch/14cf2a690a34e36370ce2d54c907e8f4 ○ 10.4 Consistency Analysis https://play.library.utoronto.ca/watch/f754470e15785544fa8ae48fa315e300 • Readings ○ Fox, M.S., (2017), "The PolisGnosis Project: Enabling the Computational Analysis of City Performance", *Proceedings of the 2017 Industrial and Systems Engineering Conference*, K. Coperich, E. Cudney, H. Nembhard, eds. http://eil.mie.utoronto.ca/wp-content/uploads/2015/06/IISE-2017-3349.pdf ○ Fox, M.S. (2015) "The Role of Ontologies in Publishing and Analyzing City Indicators", *Computers, Environment and Urban Systems*, Vol. 54, pp. 266-279. https://www.sciencedirect.com/science/article/pii/S019897151530020X?casa_token=8Sm-Wv7OISkAAAAA:5nMySUMfg29zM6CSAIxUiQGcFfmD7ZbeoVA7Jl27VDCCZ9kYCTe6vquHi5JzMM3eHyIBta7i ○ Fox, M. S. (2021). An ontology engineering approach to measuring city education system performance. *Expert Systems with Applications*, 186, 115734. https://www.sciencedirect.com/science/article/pii/S0957417421011143?casa_token=88nXfcgvYNEAAAAA:HYAqOCOQoOygPTtccJmHn2ICKfGtxOOualnd5nauCAO501P0Faau703aMtrmGAOzbutu7K1Z ○ Wang, Y., and Fox, M.S., (2017), "Consistency Analysis of City Indicator Data", in S. Geertman et al. (eds.), *Planning Support Science for Smarter Urban Futures*, Lecture Notes in Geoinformation and Cartography, DOI 10.1007/978-3-319-57819-4_20. http://eil.mie.utoronto.ca/wp-content/uploads/2015/06/CUPUM17_chapter_final.pdf
11	Inference	• Slides ○ 11.1 Rule Based Systemss http://ontology.eil.utoronto.ca/MIE1501/syllabus/W11/11.1-RBS.pdf ○ 11.2 SWRL – Semantic Web Rule Language http://ontology.eil.utoronto.ca/MIE1501/syllabus/W11/11.2-SWRL.pdf ○ 11.3 SWRL Education Example http://ontology.eil.utoronto.ca/MIE1501/syllabus/W11/11.3-SWRL-Education-Example.pdf • Recordings – must have UofT mymedia account ○ 11.1 Rule Based Systems https://play.library.utoronto.ca/watch/c9e44041a700cdf708b21e8db7ccdda4 ○ 11.2 SWRL – Semantic Web Rule Language

		https://play.library.utoronto.ca/watch/a50c8de5ce7888795f08ee77c67e90b7 ○ 11.3 SWRL Education Example https://play.library.utoronto.ca/watch/2f6a059d6f6733bacae5ec114e562265 • Readings ○ Jackson, P., (1998), "Chapter 5: Rule-Based Systems", *Introduction to Expert Systems*, Addison Wesley, pp. 76-99. http://ontology.eil.utoronto.ca/MIE1501/syllabus/W11/jackson-chap5.pdf ○ O'Conner, M., (2017), "SWRL Language FAQ", https://github.com/protegeproject/swrlapi/wiki/SWRLLanguageFAQ ○ SWRL Editor https://github.com/protegeproject/swrlapi/wiki/SWRLEditor ○ Kuba, M., (2012), "OWL 2 and SWRL Tutorial" http://dior.ics.muni.cz/~makub/owl/
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