A Framework for Evaluating the Commensurability of Semantic Web Ontologies

Liam Magee
Global Cities Institute
Structure of Talk

- Background & overview
- Introduction to:
  - The Semantic Web
  - Description Logics
  - Semantic Web languages: RDF and OWL
  - Ontology matching
- Description of problem
- Overview of framework and software system
- Some suggestive comments on potential directions and further work
  - *Maybe a bit optimistic...*
Background

- ARC involving RMIT, FujiXerox Australia, Common Ground:
- “The impact of the Semantic Web on Document Management and Print Industries”
- Focus on standards and interoperability in publishing supply chain
- 3 years – 2006 – 2009
- Major findings:
  - Semantic Web has had little impact – and little foreseeable (some reasons below)
  - Broader canvas: semantic “technologies” having increasing impact:
    - Online collaboration; Social networking; “Single sign-on” services: OpenID
    - Web services
    - Natural language processing
    - Combined services: OpenCalais (processes natural language and returns “enriched” content – with key terms mark-up as RDF)
Background – My thesis

- My thesis: “Commensurability of Semantic Web Ontologies”
- “Commensurability”: taken from Thomas Kuhn's “Structure of Scientific Revolutions” (1962):
- History of human science: a series of *incommensurable* paradigms
  - Ptolemaic → Copernican cosmology
  - Newtonian → Einsteinian physics
  - pre- and post-Lavoisier chemistry
  - pre- and post-Darwinian biology
- Michel Foucault: history of human sciences ("The Order of Things" (1966))
- Analogy between scientific paradigms and knowledge representations
- Co-ordinating work in algorithm design (ontology matching) with theories of cultural differences in social sciences
- Abstractly: “belief networks” or “conceptual schemes” can describe both *broad* historical periods and *local* “cultural” knowledge or belief systems
Criticism from Donald Davidson ("The Very Idea of a Conceptual Scheme", 1974):
- If conceptual schemes are incommensurable, then translation is impossible
- But we translate all the time...
- So account is self-defeating
- Sceptical of "scheme / reality" division

Replace binary "either/or" distinction "commensurable / incommensurability" with degree of commensurability

Hypothesis: All conceptual schemes partially translatable; a question of "effort" from a third-person point-of-view

So problem becomes (in more specific terms): how commensurable are two ontologies for a particular problem, with a given context – and how does this impact practically, in cost, time and resources?
Diagram...

- Problem for Translation
- Context of Translation
- Estimate of work
- Degree of Commensurability
- Ontology 1
- Ontology 2
- Translator
Why Ontologies?

Why semantic web ontologies?

- Explicit focus on problems of *translatability of knowledge representations* in a *formal language* on a *web-scale*
- Significant academic and industry attention
- Standardisation at syntactic and formal semantic level
- Ontology matching: shows promising results for algorithmic translation
- Reduced ambiguity relative to natural expression of theories, paradigms
- Good setting for applying relatively abstract social theoretic models
Introductions...

• Whirlwind tour of:
  - Semantic Web
  - Description Logics
  - OWL/RDF
  - Ontology Matching

• Can't do justice, but provides provisional background to framework and software
The Semantic Web

- Proposal for interconnected “web of data”
  - began circa 1998
  - envisages expression of facts in formal, logic-based languages
  - permits inferences over a global knowledge base
- Early precursors:
  - Leibniz's vision of a universal symbolism (universalis mathesis) - 17th century
    - If this done, whenever controversies arise, there will be no more need for arguing among two philosophers than among two mathematicians. For it will suffice to take pens into the hand and to sit down by the abacus, saying to each other (and if they wish also to a friend called for help): “Let us calculate!”
  - Logical positivism: vision of knowledge emphasis on logic and empiricism in 1920's
  - Common optimism: expression of knowledge in common formalism and conceptual scheme
  - Idealistic: “Logical utopianism”
Semantic Web – Linked Data
Semantic Web Components

• Essentially:
  - URI for identity, naming, location
  - XML for canonical syntax
  - RDF and OWL for semantics

• Additionally:
  - SWRL: rule language
  - SPARQL: query language
  - RDFa: embedding descriptions in XML/HTML
  - GRDDL: integrating RDF with other microformats
  - POWDER: protocol for describing resources with RDF
Another diagram...
Semantic Web Layer Cake
Semantic Web Aims

- Automated reasoning (via formal semantics, description logics)
- System interoperability (via standardised ontologies)
- On a web-scale (building on WWW infrastructure: URI, XML, web services)
- Berners-Lee et al. (Scientific American, 2001):
  - The Semantic Web, in naming every concept simply by a URI, lets anyone express new concepts that they invent with minimal effort. Its unifying logical language will enable these concepts to be progressively linked into a universal Web. This structure will open up the knowledge and workings of humankind to meaningful analysis by software agents, providing a new class of tools by which we can live, work and learn together.
Trends at a glance...

• Modest success
  - domains with large classificatory problems (life sciences)
  - regions with clear interoperability needs (EU)
• Refinements to OWL (OWL 2)
• Development of ontologies, including upper-level ontologies, biological ontologies
• “Real-world” case studies (HP, IBM, Xerox)
• Lots of small start-ups (OpenCalais (now Thomson Reuters), Twine, Talis)
• Integration with “conventional” IT infrastructure, standards: RDFa (embedded RDF in HTML); GRDDL (integration with microformats); SPARQL (SQL-like language for querying ontologies)
• emergence of “loose” semantic services: combines RDF, natural language processing and web services to “mark-up” natural languages
• Semantic web – diluted into general “semantic technologies” (terminological slippage)
Criticisms at a glance...

• Futuristic: “Web 3.0”, “Web 4.0” etc = over-hyped technology by many in industry

• Anecdotal comment: original humble goals of RDF corrupted by KR community

• Difficulties of explaining ontology engineering principles to business community – issues of unfamiliar vocabulary and complexity:
  - What is an ontology? A class? A property? An individual?
  - Investigation of W3C specs very different to, say, HTML or XML: for example: RDF, OWL, OWL sub-languages, model theory, description logics, entailment, proofs, logic symbolism, proofs, expressivity, tractability, non-monotonicity, defeasible reasoning, subsumption, predicates, domain, range, transitivity, symmetry, reflexivity, associativity, functional and inverse functional properties, union, intersection, complement, disjunction, cardinality, reification, intensionality/extensionality, ALC, SH(\text{IF} / \text{OIN} / \text{OIQ})
  - OK (perhaps) for those with interests in AI and knowledge representation; obscure to IT and business communities

• All this for what? High cognitive requirement for relatively little pay-off

• Ontology commensurability: what guarantees are there for agents to negotiate and agree on extensional meanings of ontologies?
Some evidence of hype cycle (Gartner)

- "Peak of Inflated Expectations" - 2001 – 2005
- "Slope of Enlightenment" - 2008 – 2010
- "Plateau of Productivity" - 2010?
Open Challenges

• Tools, libraries (no VisualStudio, Eclipse)

• “Insulating” layers of abstraction

• Reconcile contradictory aims:
  – KR (and associated philosophical challenges)
  – Practical resource description, metadata for the web

• Integration with existing infrastructure

• Clear statement of business value proposition

• May be “niche status” only
Description Logics - background

- Description Logics: foundation of RDF and OWL
- Early efforts to develop knowledge systems – semantic networks (Quillian, 1967) and frames (Minsky, 1981)
  - approximate human representations of knowledge (Sattler, Calvanese, Molitor, 2003)
- Lacked a formal Tarski-style semantics → imprecise, conflicting interpretations, differences in system implementations (Nardi, Brachman, 2003)
- KL-ONE (Brachman, 1979): First attempt to build workable knowledge representation system with foundation on predicate logic with a model-theoretic semantics:
- Research since focussed on developing description logics with:
  - high expressivity
  - low computational complexity (i.e. tractable)
  - OWL DL and OWL 2 are implementations of SHOIN and SHOIQ description languages respectively (see below)
  - Balance of expressivity and tractability
Description Logics - foundations

• Description logics: fragments of FOL (predicate logic), with following language elements:
  – Unary predicates (concepts)
  – Binary predicates (roles)
  – Constants (individuals or objects)

• Two-place predicates makes description logics closely related to multi-modal logics

• In intuitive terms: in description logics, concepts and roles can be used to describe objects

• Statements about intensional (definitional) meaning of concepts are terminological – for example: “All books are documents”. Set of terminological statements = T-Box.

• Statements about extensional (in the world) meaning of concepts are described as assertional – for example: “This copy of War and Peace is a document”. A set of assertional statements = A-Box.

• Together terminological and assertional statements (T-box and A-Box) form a knowledge base.

• Reasoning over DL knowledge base usually employs tableau algorithms to determine T-Box (true definitionally) and A-Box (true by extension) satisfiability (Horrocks, 1997)
Description Logics – constructors (I)

- Description logics are distinguished on the basis of various constructors (Baader, 2003):
- Basic dialect: AL (Attributive Language) with:
  - Atomic concept
  - Universal concept
  - Bottom concept
  - Atomic negation
  - Concept intersection
  - Value restriction
  - Limited existential quantification
Description Logics – constructors (II)

- U: concept union
- E: Full existential quantification (arbitrary concepts allowed to occur in the scope of the existential qualifier)
- C: Complement, negation of arbitrary (non-atomic) concepts
- N: Number restrictions
- Q: Qualified number restrictions
- H: role hierarchy
- O: Nominals or constants
- F: Functional roles
- I: role inversion
- S: role transitivity
- ALC: Attributive Language with Complements → becomes 'S'; additional features then added:
  - Commonly investigated variants: SHIF, SHOIN, SHOIQ
  - Many more detailed tutorials online (see in particular DL complexity navigator - http://www.cs.man.ac.uk/~ezolin/dl/)
The concepts woman, mother, parent are satisfiable

- how about NOT(woman) & mother?

\[
\neg\text{woman} \sqcap \neg\text{mother} \\
\neg\text{(female} \sqcap \neg\text{person}) \sqcap \text{female} \sqcap \text{parent} \\
(\neg\text{female} \sqcup \neg\text{person}) \sqcap \text{female} \sqcap \text{parent} \\
(\neg\text{female} \sqcup \neg\text{person}) \sqcap \text{female} \sqcap \text{parent} \\
\neg\text{person} \sqcap \text{female} \sqcap \text{parent} \\
\neg\text{person} \sqcap \text{female} \sqcap \text{person} \sqcap \exists\text{has\_child}\text{.person} \\
\neg\text{person} \sqcap \text{female} \sqcap \text{person} \sqcap \exists\text{has\_child}\text{.person}
\]

- The conjunct NOT(woman) & mother can never be satisfied
- (Adapted from Spencer 2005)
Description Logics - notes

• In description logics: concepts / classes defined by roles / properties they are associated with (as domain arguments)

• Relational and object-oriented paradigms: properties (roles) defined by classes (concepts) they are associated with:
  - Isomorphism at a formal level (Calvanese et al, 1998)
  - But problems of cognitive dissonance and “impedence mismatch” at an implementation level (cf. Declarative vs imperative programming)

• Extensions of description logic have been explored for various specific problems:
  - Capturing defeasible reasoning using non-monotonic logic operators
  - Capturing time concepts using temporal logic operators
  - Capturing uncertainty and ambiguity using fuzzy description logic operators
OWL & RDF – DL's applied

- **Vocabulary shift:**

<table>
<thead>
<tr>
<th>Sentence types in Knowledge bases</th>
<th>Description Logic</th>
<th>RDFS/OWL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Term (T-box)</td>
<td>Concept</td>
<td>Class</td>
</tr>
<tr>
<td>[Role (R-box)]</td>
<td>Role</td>
<td>Property</td>
</tr>
<tr>
<td>Assertion (A-box)</td>
<td>Object/Individual</td>
<td>Individual</td>
</tr>
</tbody>
</table>

- **Semantic relationship:**

<table>
<thead>
<tr>
<th></th>
<th>RDFS</th>
<th>OWL Full</th>
<th>OWL DL</th>
<th>OWL Lite</th>
<th>OWL 2</th>
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<td>FOL</td>
<td>SHOIN</td>
<td>SHIF</td>
<td>SHOIQ</td>
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<td>Complexity</td>
<td>Undecideable</td>
<td>Undecideable</td>
<td>NEXPTime</td>
<td>EXPTime</td>
<td>NEXPTime</td>
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RDF & RDFS (Schema)

- RDF: Resource Definition Framework – provides mechanism for adding information to resources in formal language:
  - Every statement is a triple of the form: subject predicate object
  - “This webpage is authored by Liam Magee” → http://page.com isAuthoredBy http://page.com/#Liam_Magee.
- RDFS: Schema language for RDF. Introduces (undecidable) logic for describing basic structure of an ontology:
  - Classes
    - rdf:Class (corresponds to DL concept)
    - rdf:Property (corresponds to DL role)
    - rdf:Resource (any thing to be described)
    - rdf:Literal (specifies some literal value)
    - rdf:Datatype (string, integer, etc.)
    - rdf:XMLLiteral (some XML literal value)
RDFS - Properties

- Properties
  - rdfs:domain & rdfs:range (specifies property arguments)
  - rdf:type
  - rdfs:subClassOf & rdfs:subPropertyOf (specifies subsumption relationships)
  - rdfs:label & rdfs:comment (annotations)

- Properties with ranges:
  - of rdf:Datatype are Datatype Properties
  - of some rdf:Class are Object Properties

- Other vocabulary:
  - Collections: rdfs:Container; rdf:Bag, etc
  - Reification (statements about statements): rdfs:Statement; rdf:subject; rdf:predicate; rdf:object
  - Utilities: rdfs:seeAlso; rdfs:isDefinedBy; rdf:value
OWL - Constructs

- Builds on RDF – adds further logical constructs to aid reasoning
- Classes:
  - Value constraints: owl:allValuesFrom; owl:someValuesFrom; owl:hasValue
  - Cardinality constraints: owl:maxCardinality; owl:minCardinality; owl:cardinality
  - Set operations: owl:intersectionOf; owl:unionOf; owl:complementOf
  - Relation to other classes: owl:equivalentClass; owl:disjointClass;
- Properties:
  - Functional properties: owl:FunctionalProperty; owl:InverseFunctionalProperty
  - Logical properties: owl:TransitiveProperty; owl:SymmetricProperty
- Individuals:
  - owl:sameAs; owl:differentFrom; owl:AllDifferent
- Datatypes: inherits from XML Schema (xsd:integer, xsd:string, etc.)
- Utility elements: Annotations, metadata, version information, import statements
RDFS & OWL notes

• OWL DL (Lite, 2) differ from RDFS and OWL full – Class, Property and Individual are mutually disjoint

• In RDFS & OWL:
  – *Class* can be an *instance* of itself
  – *Property* can be domain, range arguments of *Property*

• RDFS & OWL:
  – Monotonic (further information cannot invalidate existing entailments)
  – Open World Assumptions (if a fact is not specified, it is unknown)
OWL – In use

- Development tools: Protege, SWOOP
- Reasoners: FACT, Racer, Pellet
- Search engines: Swoogle
- Repositories: OBO (Open Biomedical Ontologies)
- Fields of application: Life sciences, citations, upper-level ontologies
Ontology Matching

• Vision for Semantic Web: production of many domain-level ontologies. Benefits:
  − conceptual re-use, through ontologies imports
  − inferences: explicit class equivalence (owl:equivalentClass); individual equivalence (owl:sameAs)
  − hopes of gradual ontology standardisation (de facto, de jure processes)
  − promises web-scale interoperability (“web of data”)

• In practice, different ontologies are produced with:
  − High cost of establishment semantic equivalences
  − High cost of human translation between ontologies

• Ontology matching developed:
  − builds on prior research in database and XML schema matching (Shvaiko & Euzenat, 2005)
  − find automated means of matching concepts from ontologies (basis for automated translation of instances)
Ontology Matching Outputs

- Typical outputs of ontology matching algorithms contain mappings:
  - id of the mapping
  - $e, e'$ are the entities of two schemas or ontologies
  - $n$ is the confidence measure of the match
  - $R$ is relation between entities: conceptual equivalence; generalisation; disjointness; or intersection (Shvaiko & Euzenat, 2005)

- Shvaiko & Euzenat (2005): taxonomy of matching approaches:
  - Schema-based versus instance-based
  - Element-level versus structure-level:
    - Element-level: concepts in isolation
    - Structure-level: concepts + conceptual relations (subsumption, etc.)
  - Syntactic vs external vs semantic analysis:
    - Syntactic: syntactic features of input; tokenising, lemmatising concept names
    - External: use of external authority (e.g. WordNet dictionary; domain-level thesauri; shared upper-level ontologies)
    - Semantic: semantic features (subsumption, etc.); validity between two concepts if negation of a proposition containing the concepts is unsatisfiable
Ontology matching exploits explicit “ontological commitments” of ontologies.

Common aim is to generate accurate concept-to-concept mappings.

Ontology matching can be used as the basis for conventional data operations:
- Data migration (moving data from system A to system B)
- Data warehousing (moving data from systems A and B into system C)
- Data integration (extracting data from systems A and B into a shared view)

Main claim here: concept-to-concept mappings are a necessary but insufficient basis for ontology matching in practical scenarios.
More on the problem...

- Problems with sole reliance upon ontology matching:
  - Methodological reasons - Ontology construction employ differing methods of classification
  - Teleological reasons - Ontologies are developed and used for different purposes;
  - Epistemological reasons - Ontologies imply different epistemological frames or paradigms – background knowledge
  - Conceptual reasons – rivals to necessary and sufficient conditions for class inclusion
    » Prototype theory (Wittgenstein, 1951; Rosch, 1975)
    » “Theory” theory (Murphy & Medin, 1999)
  - Pragmatic reasons – partiality of knowledge representations
  - Operational reasons
    • Automated ontology matching referenced against human mappings
    • Even “best” mappings are not universally applicable
  - Semantic reasons
    • No guarantees of concept extensional equivalance
    • Semantic relations discovered are fragmentary (i.e. programming constructs of XSLT)
    • Open question of how to handle open contradictions (ontology A says X is a Y; ontology B denies it) – trust, defeasible reasoning
Practical requirements

- Ontology matching often needs:
  - Background knowledge - supplementary axioms – what other commitments
  - Understanding of context of ontology production
  - Understanding of context of ontology matching
  - Transformation rules – what specific context-related rules are required to transform instances of concept A to concept B

- These problems: generalisable to problems of translatability of any conceptual formalisms
  - Analogy with what is needed in everyday natural language contexts
Another Diagram...

- Translator
- Problem for Translation
- Context of Translation
- Estimate of work
- Degree of Commensurability

- Ontology 1
- Ontology 2
- Background
Some objections...

- Ontology matching: sufficient for many applications and purposes (agreed!)
- Ontology matching is not posed as a “silver-bullet solution”: are you asking too much? (yes!)
- Is problem just one of making more explicit assumptions?
  - Epistemological problem:
    - A. adequacy of logics (description logics or otherwise) to represent all kinds of knowledge (Strong AI thesis (Fetzer, in Floridi (2004)))
    - B. adequacy of human agents to provide accurate knowledge
    - probable answer is “unknown” for A; “no” for B – not all kinds of knowledge have adequate discovery procedures (particularly in the human or social sciences)
Proposed Approach...

- Proposed approach: compares *cultural conceptual schemes, belief networks*
  - complementary to ontology matching
  - a generalised conceptual holistic *understanding* of ontologies for particular *atomistic* interpretations of concept-to-concept relations
  - Philosophical aside: hermeneutic circle...
- Problem becomes: understanding cultural perspective which “orients” an ontology
  - Why *these* conceptual distinctions, and not others?
  - Profiles ontologies or schemas - look for background, implicit cultural beliefs
  - By “culture”: organisation, community, collective, group with shared *beliefs* and *practices* which influence production of cultural artefact
  - Knowledge representations treated as cultural artefacts
Ontology as Perspective
Hermeneutic Circle

P = pre-understanding,
U = understanding;
P_1 = advanced pre-understanding;
U_1 = advanced understanding ...
Framework and Software

- Complement ontology matching approaches by
  - Modelling *cultural conditions* of ontology production and matching
- Purpose: provide analysts with:
  - Diagnosis of potential problem areas
  - Better estimates of feasibility and scope of work
  - Awareness of areas where supplementary assumptions are needed
- Heuristic – intended to *guide* rather than *direct*
- Limited epistemological claims:
  - Implicit knowledge requires interpretation – prima facie *subjectivist*
  - Modelling cultural perspectives makes use of sources (documents, interviews, etc) – subject to qualitative interpretation.
- But: as *supplementary* evidence: claimed that interpretive work *useful*
Framework overview

- Framework is:
  - Taxonomy of *dimensions* for profiling ontologies
  - Lightweight *methodology* for analysing sources about ontologies
  - Mechanism for *reporting* on the commensurability of ontologies
Framework Dimensions (I)

- Dimensions: a two-tier taxonomy:
  - Structure (how are concepts organised?)
  - Style (how ontology is written)
  - Subject (what ontology describes?)
  - Semantics (truth status of the ontology?)
  - Process (how is the ontology \textit{developed}?)
  - Practice (how is the ontology \textit{used}?)
  - Purpose (\textit{why} is the ontology developed?)
  - Perspective (what point of view?)
  - Relational (how do \textit{two} ontologies relate?)
Framework Dimensions (II)

- Distinction between schema and relationship dimensions
- Categories organised “inside out”
  - moves from internal to external analysis
- First tier (general dimensions):
  - Intended to be answered *qualitatively*
- Second tier (specific dimensions/variables):
  - Intended to be answered *quantitatively*
- Intended that dimensions are reviseable, extensible and weightable
Methodology

- Redacted form of social science methods
- Analyse textual evidence to generate
  - stand-points of actors/agents developing / using ontologies
- Intended as lightweight, practical approach of getting at implicit beliefs and knowledge
- Applied to evidentiary sources: academic papers, online forums, websites, mailing lists, company annual reports (unobtrusive sources); interviews, surveys (obtrusive sources)
- Applies a simple coding procedure to sources – then used to drive dimension valuations
- Intended to get “quick picture” of perspectives underlying constructions of ontologies and other formalisms
- In practice, not so quick...
Reporting mechanism:

- Generates averages
  - Mean
  - Dimension weighted mean
  - Group dimension weighted mean
  - Dimension and dimension group weighted means

- Evaluates commensurability against predefined limit
Work in progress

- Applied to thesis case studies:
  - Document formats (Microsoft OOXML versus OASIS ODF)
  - Upper-level ontologies (SUMO, DOLCE, several others)
  - Biological ontologies (genetic versus physiological classification of biological objects)
  - Formalisms themselves (relational versus description logics “view” of information)

- Attempted to “operationalise” framework in software
  - to obtain some external evaluation of the utility of the framework
Software operationalises framework:
  - Generalised to knowledge representation schemas (to reach a broader audience)
  - Has further specific support for OWL ontologies
  - Will generate metrics about:
    - Number of classes
    - Number of properties
    - Ratio of object to datatype properties

Uses project context for profiling schemas

Basic example: compares two common tutorial ontologies (wine and a pizza ontology)
Software Steps

- Describe a project: “The Pizza and Wine Project has been initiated to help a restaurant build a new order management system.”
- Modify dimensions to suit project context
- Add documentary sources
- Add and profile two (or more) schemas
- Construct a matrix (quantitative comparison of schemas against the dimension set)
- Develop an analysis (qualitative assessment of the commensurability of the schemas)
- Generate a report - includes:
  - introduction - project description
  - methodology
  - individual schema profiles
  - findings: qualitative, quantitative
  - analysis and conclusion
- Then give me an evaluation
### Construct the matrix

**Show help**

Go to: schema or relationship dimensions, or summary | Show additional functions

### Schema Dimensions

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Wine (cnt)</th>
<th>Pizza (cnt)</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure</td>
<td></td>
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<td></td>
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<tr>
<td>Small-Large</td>
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<tr>
<td>Self-contained-Derivative</td>
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<td>Shallow-Deep</td>
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<td>Sparse-Dense</td>
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<td>Free-Restricted</td>
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<td>Classificatory-Attributive</td>
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<tr>
<td>Literal-Object Composition</td>
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<tr>
<td>Qualititative - Quantitative</td>
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<tr>
<td>Low - Highly Annotated</td>
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<td>Sparsely-Heavily Populated</td>
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<td>Semantics</td>
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<tr>
<td>Simple - Complex</td>
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<tr>
<td>Specific - General</td>
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### Actions:

- Review project info
- Browse sources
- Compare metadata
- Compare metrics
- Review Wine
- Review Pizza

### Metrics

<table>
<thead>
<tr>
<th>Metric</th>
<th>Wine</th>
<th>Pizza</th>
</tr>
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<tr>
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<td>Class/property ratio</td>
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<td>Annotation/axiom ratio</td>
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<td>DL expressivity</td>
<td>SHOIN(EU)</td>
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<tr>
<td>Average number of named axioms</td>
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<td>Object property count</td>
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<td>Logical axiom count</td>
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</table>
Another one...

### Overall Commensurability Ratings

The following table displays the following overall average commensurability ratings between the Wine and Pizza schemas:

- Normal (unweighted) averages
- Averages weighted by the dimension weights
- Averages weighted by the dimension group weights
- Averages weighted by the dimension and dimension group weights

<table>
<thead>
<tr>
<th>Schema Commensurability Rating</th>
<th>Average Commensurability Value</th>
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<tbody>
<tr>
<td>Average:</td>
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<tr>
<td>Weighted Average:</td>
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<td>Weighted Group Average:</td>
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<td>Weighted Group and Dimension Average:</td>
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</table>
Aim and Feedback

• Aim:
  - to get external feedback on framework and software
  - and refine
• So far: not a lot of excitement...
• Looking for participants!
Suggestive Comments

• Framework: crude modelling tool - further work:
  - Commensurability as “game”, with ontologies as “players”, and matches as “moves”
  - General communications between agents/actors/players
  - Improve model of “perspective”
  - Relation to other modelling approaches – artificial societies, social modelling

• Use of epistemic logics to model (a) explicit beliefs of an ontology; (b) implied background beliefs

• Analogies with modelling agent beliefs – so possibly something to learn from work done in BDI framework

• Intersection between social sciences and ontologies:
  - How can social science methods be applied to understanding of knowledge representations
  - Conversely: how can robust ontologies improve social science modelling?
Finally...

- Thank you...
- Questions?