FUTURE OF ONTOLOGISTS

Acknowledgemnts

This study was conducted by the Ontology community and The Millennium Project for the Ontology Summit 2010.

Special thanks go to Peter Yim, President of CIM Engineering, San Mateo, CA, USA, coordinator of the study, to Ted Gordon and Elizabeth Florescu for running the RTD, as well as the entire Ontology community for their great contributions.

Note: the term "Ontology" refers to a new scientific and engineering discipline (like Biology or Life Science or bio-engineering), as well as the engineering/analytical methodology, technology and artifacts that come from that discipline.
"What are Ontologies" <http://ontolog.cim3.net/OntologySummit/2012/ontology.html> explains:

> *Ontology engineering arose as an answer to a “problem” in computing.*
> *The word “ontology” has been used to refer to a wide range of computational artifacts of varying complexity, ranging from folksonomies (tag clouds), controlled vocabularies, taxonomies (Yahoo! directory), thesauri (Wordnet) to logical theories of reality (Basic Formal Ontology, DOLCE).*
> *As our world becomes more complex, ontologies are a vital piece of a solution addressing the problems of Big Systems and Big Data.*
> *Finally, as we move into the knowledge age there is a growing expectation that our systems will be more self-describing and intelligent. In order to engineer such systems, allow intuitive use and meet expectations of all stakeholders, a more consistent and complete use of ontologies and ontological analysis must be made.*

EXECUTIVE SUMMARY

“An ontology is a specification of a conceptualization” - so published Stanford computer scientist Dr. Tom Gruber back in 1992, as he defined, for the first time, the term "ontology" in the sense we apply to its use in computer science, artificial intelligence and the Semantic Web today.

Some purport that ontology will potentially have an impact on humanity more profound than the one caused by the Internet. Today, ontology is being regarded as an emerging science and engineering discipline, analogous to “computer science” about 50 years ago. Ontology for information science (not the branch of study in philosophy that deals with “being” that is a part of metaphysics, and from which it is derived) is a layer of abstraction that provides the formal, explicit specification of a shared conceptualization, expressed in a language that can be parsed by machines. Ontologies are used in fields like artificial intelligence, the semantic web, systems engineering, software engineering, biomedical informatics, and library science. They form the underpinnings that allow data to “interoperate” or for machines to be able to make useful “inferences.”

Computers don’t know what exists in the world; somebody has to tell them, and those people will likely be ontologists. This will have to be done meticulously, or else machines will draw bad conclusions. Ontologists are highly trained professionals with interdisciplinary skills and knowledge in areas like logic, computer science, mathematics, semantics, knowledge representation, formal and informal ontology, automated reasoning, and computational linguistics.

Major projects advanced by governments, scientific, and business organizations increasingly require ontology technology. This triggers a growing demand for ontology expertise and thus for new methods and institutions for training ontologists. Under the theme “Creating the Ontologists of the Future,” the Ontology Summit 2010 explored the current state of ontology and ontology training, likely developments affecting the future of ontologists, strategies to address educational methods and standards, ontology applications, and associated resources. (For Summit information, see ontolog.cim3.net/cgi-bin/wiki.pl?OntologySummit2010.)

Information on what the future for ontologists might look like was collected from the community experts through a three-month series of virtual debates and three online questionnaires that explored, respectively, the present ontology education/training content and quality, the knowledge and skills ontologists need or are expected to have in a variety of working contexts, and a Real-Time Delphi to collect expert opinion on the future of ontologists and the field of ontology.

The results and recommendations of the Ontology Summit 2010 are summarized in the Communiqué “Creating the Ontologists of the Future”—see section 3. The main findings are (excerpt from the Communiqué):

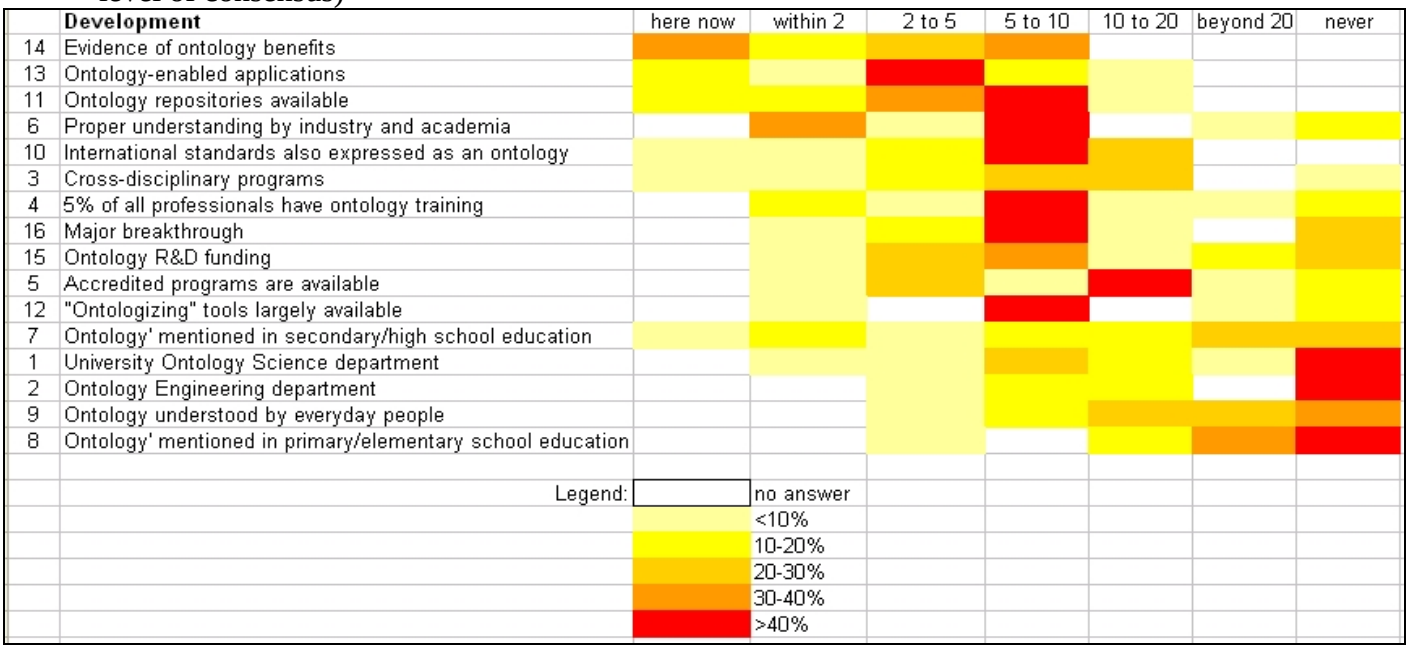
1. There is already a large demand for trained ontologists, and the demand is expected to increase as ontology-based technologies become more successful and as the quantities and number of different types of data continue to expand.
2. There are very few formal training opportunities for ontologists, and they often do not meet the needs of trainees or of those who would hire them.
3. Organizations that want to hire ontologists often have difficulties in identifying qualified candidates since there are so few formal qualifications in ontology, and there is no professional organization that certifies ontologists.

The Communiqué also contains recommendations concerning the body of knowledge that should be taught and the skills that should be developed by future ontologists, and it suggests actions that would improve the education of ontologists.

The Millennium Project was invited to provide futures research expertise and conduct the RTD "Future of Ontologists" study. The questionnaire used a set of 16 developments distilled from suggestions provided by the experts' community. For each development, the participants were invited to give input as to when the development would occur as well as comments on factors that might help and/or hinder its happening. The 35-people panel consisted of ontology domain experts, those who can influence the future of the field, and visionaries who understand what the potential impact of ontology might be. Section 2 of this subchapter presents the questionnaire and a detailed analysis of the results.

Figure 1 illustrates the panelists' estimates of when each of the "developments" is likely to happen, as well as the level of consensus.

Figure 1. Developments rank-ordered by time frame of occurrence (the color coding shows the level of consensus)



Some general developments that the ontology-experts community sees imperative include:

- Clearly define the discipline so that the field can settle in (now, even practitioners are sometimes confused).
- Increase investments in education and R&D that enhance the potential impact that ontology promises.
- Develop a required body-of-knowledge and curricula to provide reference for educators and trainers.
- Develop compelling applications so that others outside of the field can appreciate the value of the ontological approach.
- Develop tools that would allow ontologies to be applied more widely rather than just by experts.

The key findings and observations generated by the RTD study are:

- There is high consensus that a lot of these developments will be happening in the next 5–10 years.
- A large number of people with proper ontology education and training will be needed in a 5–10 year time frame (about 5% of information systems and software engineering professionals would need ontology training).
- Given that education and training should be in place before those demands occur, the sense of urgency to do that promptly and properly should not be taken lightly.
- The study of ontology will likely show up as cross-discipline programs rather than as an ontology science or ontology engineering department in universities.
- A fair number of participants believed that there is already (or will soon be) good evidence on the benefits of the ontological approach, exemplified by progressively compelling ontology-driven applications, available ontology repositories, and adoption by international standards, which will help drive a better understanding of ontology and its value by industry and academia.
- While R&D funding is supposed to be a leading indicator of growth in the field of ontology, there is no consensus on its availability, and it appears that it might lag the time frame of other developments.
- Somewhat lagging as well are the availability of tools that might enable the wider adoption of the ontological approach.
- It is also generally believed that the discipline of “ontology” will not likely be understood by the masses and, while ontology education might eventually move into secondary/high school education, it is unlikely that it will show up in primary/elementary schools.

Some trends that were identified include:

- Semantic search techniques and semantic web will become prevalent.
- Ontologies will be a foundational component for semantic technologies and knowledge-based systems.
- The field of ontology will transcend domains/markets, etc.
- Routine use of ontology will enable a revolution in the flexibility of information systems, expanding them beyond their original purpose.
- Tools/technologies/best practices will continue to emerge to support the field; in 20 years, ontology might be just a background information that everyone is used to.

1. INTRODUCTION

A Study on the "Future of Ontologists and their Education"

“An ontology is a specification of a conceptualization” - so published Stanford computer scientist Dr. Tom Gruber back in 1992, as he defined, for the first time, the term "ontology" in the sense we apply to its use in computer science, artificial intelligence and the Semantic Web today.

Computers don’t know what exists in the world; somebody has to tell them, and those people will likely be ontologists. This will have to be done meticulously, or else machines will draw bad conclusions. Highly trained professionals with interdisciplinary skills and knowledge in areas like logic, computer science, mathematics, semantics, knowledge representation, formal and informal ontology, ontology languages, ontological engineering, automated reasoning, semantic technology applications, computational linguistics, etc. are called for.

Some believe that Ontology may bring an impact to humanity that is more profound than that which is being brought forth by the Internet (or even computer science.) Today, “Ontology” can be regarded as an emerging science and engineering discipline, analogous to the position where “computer science” was about 50 years ago. Ontology for Information Science (not the branch of study in philosophy that deals with “being” that is a part of metaphysics, and from which this term is derived) is a layer of abstraction that provides the formal, explicit specification of a shared conceptualization, expressed in a language that can be parsed by machines. Ontologies are used in fields like artificial intelligence, the Semantic Web, systems engineering, software engineering, biomedical informatics, and library science. They form the underpinnings that allow data to “interoperate,” or for machines to be able to make useful “inferences.”

Major projects advanced by governments, scientific, and business organizations increasingly require ontology technology. This triggers a growing demand for ontology expertise and thus for new methods and institutions for training ontologists.

Under the theme “Creating the Ontologists of the Future,” the Ontology Summit 2010 was the 5th of its kind (after it was first launched in 2006.) This program series is jointly organized by NIST, Ontolog, NCOR, NCBO and IAOA.* The Summit was launched on December 10, 2009, and, like previous years, it comprised three months of virtual discourse, over the Ontolog-archived mailing lists, wiki, surveys and virtual panel sessions, and culminated in a two-day face-to-face symposium held at NIST (Gaithersburg, Maryland, USA.)

The 2010 Ontology Summit explored strategies to address the needs in terms of curriculum, establishment of new career tracks, role of ontology support organizations and funding agencies, as well as training in the analysis and comparison of methodologies for designing, maintaining, implementing, testing and applying ontologies and associated tools and resources.

Before the conveners could make a meaningful attempt to craft the strategies for "Creating the Ontologists of the Future," there had to be established some shared vision of what the future landscape would be like for the emerging science and engineering discipline of Ontology.

Organizers of the Ontology Summit invited The Millennium Project to provide futures research expertise, and join them in conducting a Real Time Delphi study on the "Future of Ontologists and their Education" (as one of the three surveys that were conducted as part of the summit activities.) This effort has been championed by Elizabeth Florescu and Peter Yim, with Ted Gordon and Jerry Glenn serving as advisors to the study.

The RTD "Future of Ontologists" questionnaire used a set of 16 developments distilled from suggestions provided by the experts' community. For each development, the participants were invited to give input as of the timeframe the development would occur, as well as comments on factors that might help and/or hinder its happening. The key question for each development was "What is your time estimate for this development to happen?" Panelists were also invited to support their answers with reasons, drivers that may help bring about the development in question, as well as barriers and ways to mitigate those barriers. The 35-person panel comprised ontology domain experts, those who can influence the future of the field, and visionaries who understand what the potential impact of ontology might be.

This chapter presents the results of the study. The results and recommendations of the Ontology Summit 2010 are summarized in the Communiqué "Creating the Ontologists of the Future", are also available on the Ontology Summit 2010 website (http://ontolog.cim3.net/cgi-bin/wiki.pl?OntologySummit2010.) The website also presents the details of the RTDelphi (see http://ontolog.cim3.net/cgi-bin/wiki.pl?OntologySummit2010_Survey#nid28DS) as well as of the other questionnaires, the discussions during the Summit, and at the concluding meeting.

See Ontology Summit 2010
http://ontolog.cim3.net/cgi-bin/wiki.pl?OntologySummit2010

***Acronyms:**

NIST - (US) National Institute of Standards and Technology

Ontolog - a.k.a.Ontolog Forum, a virtual community of practice for ontologists

NCOR - (US) National Center for Ontological Research

NCBO - (US) National Center for Biomedical Ontologies

IAOA - International Association for Ontology and its Applications

RESULTS OF THE REAL-TIME DELPHI

FUTURE OF ONTOLOGISTS

Future Landscape for the Field of Ontology and Possibilities for its Education and Training

Results of the Real-Time Delphi

SUMMARY

The 'Future of Ontologists' Real-Time Delphi study was conducted to collect views on the potential future landscape for the field of ontology, and possibilities for its education and training, as an input for the Ontology Summit 2010.

Participants:
A total of 35 ontology experts participated in the study: 5 from Europe, 2 from South America, and 28 from North America.
The sectoral demographic was more balanced:

Academic: 25.71%
Private Sector: 28.57%
NGO: 14.29%
Government Agencies: 11.43%
Consultants and other: 20%
Other=2.86%

General observations:
The results show a fairly good level of agreement as of the potential future developments related to the ontology field recognition and associated education.
Due to very disproportionate regional demographic of the participants, a regional analysis on the trend of opinions would be inappropriate.

Some general observations include:

- strong confidence that between 5 to 10 years, "The terms and the disciplines of "Formal Ontology" and "Ontology in Information Science" are properly understood by academia and industry (in related fields)" (Q6[1])
- the academia and industry should understand the potentials of ontology as well as the increasing need for ontologists
- the general public doesn't really need to understand what ontology is
- the highest confidence is in the recognition of the ontology's benefits
- there is high confidence regarding the use of ontology (from use in international standards to emergence of other "ontology-enabled" applications)
- funding for ontology is behind the timeframe of developments
- most developments that have a high level of agreement will occur within 5 to 10 years (including a major breakthrough)

concerning education specifically:

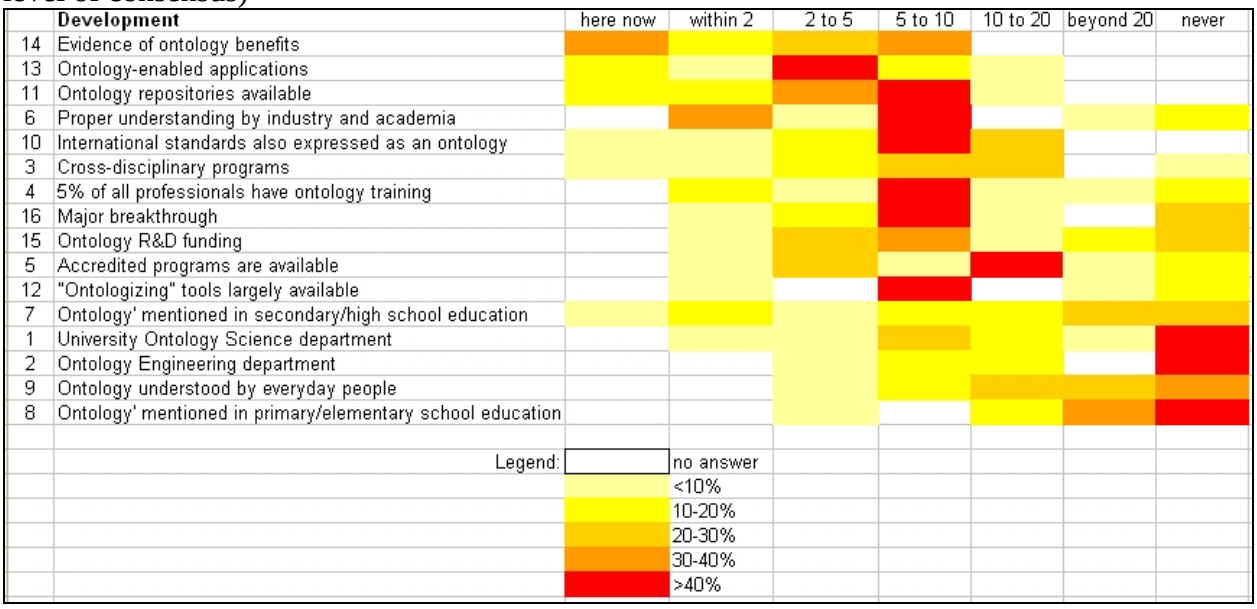
- high level of agreement that between 5 to 20 years, at least 10 universities will have cross-disciplinary programs in Ontology Science and/or Engineering department offering Master degrees (for career professionals) or PhD degrees (for researchers)' (Q3)
- skepticism that ontology departments will be created at universities (Q1; Q2)

[1] "Qx" represents the question number in the questionnaire.

- there is no specific need that the term “ontology” be taught at lower than university education levels

Figure 1 shows the developments rank-ordered by the time-frame of occurring, with the color-coding providing a quick visualization on the level of consensus, polarization of opinions, or if the results were inconclusive among the panelists.

Figure 1. Developments rank-ordered by the timeframe of occurring (the color coding shows the level of consensus)



Ontology in the Academia

There was a high level of agreement that there is no necessarily need for a university Ontology Science (Q1) or Ontology Engineering (Q2) department, most respondents agreed that in 5 to 20 years ‘On a global basis, at least 10 universities have cross-disciplinary programs in Ontology Science and/or Engineering department offering Master degrees (for career professionals) or PhD degrees (for researchers)’ (Q3).

As some respondents explained:

> *Too specialized.*
>
> *If such specialized training comes to exist within the university, my guess [is that] it would take the form of a concentration within an existing department or a multi-disciplinary program.*
>
> *It is not a big enough subject to warrant this number of departments. Normally ontology (computer science) would be part of a computing department of some sort rather than a department in its own right.*
>
> *I can much sooner imagine a department for semantic technology than I can of ontology science.*

Universities will need to define the value proposition for funding such departments and recruiting faculty.

The comments also show that the main impediment to advancing ontology in higher education is a lack of clear understanding of the field:

Many areas of knowledge need to recognize the need of going from semantic-less data to semantic-full data

Clearly defined fields of ontology and ontological engineering as a distinct field from, e.g., data modeling, knowledge representation, logic.

Have a clear differentiation between Ontology as a science (like Physics, Biology or Psychology), and Ontology as a branch of engineering (like electronic engineering, operations research), as well as Ontology as a cross-discipline support service (like project management, accounting)

[Have a] unified vision for ontologies.

One respondent commented that a great impediment for ontology penetration in the academia is "Lack of recognition of computational thinking as a fundamental cognitive skill."

Secondary/High School Education

Although opinions were very scattered concerning the potential and timing of '"ontology" word, and teaching of the basics of it' (Q7) showing up in secondary/high school education, there was high agreement that it would take over 20 years (most considering "never") to get into primary/elementary school education. Nevertheless, one respondent's opinion is that there are higher chances for "the word "ontology" and fostering ontology relevant skills" to appear in elementary education before the secondary one, due to greater flexibility of the curriculum and interest in developing forward thinking skills.

Ontology Training

There was also a high level of agreement that in less then 10 years "At least 5% of all professionals in system architecture, systems design and engineering, software engineering and information technology will be required to have proper ontology training (and a larger number will need some background in ontology)" (Q4).

This was corroborated by the responses on the timeframe for accredited programs in other fields (Q5), where the majority of respondents estimated that they will be available between 10 and 20 years. "Once ontology-related programs have been established as part of accredited educational/professional institutions, and as part of departments with other accredited programs, the next natural step is to apply for accreditation of ontology-related programs," explained a respondent. The idea was reinforced by another participant: "It takes more than a couple of years

to get from a situation where there is training, to some certification by, or creation of, some accrediting body of similar standing to, say the IET (in UK) or IEEE (US)."

Nevertheless, some respondents were skeptic about the future training programs because of "(1) Lack of agreement of what "Ontology" is, how to apply it, and how to educate learners about it; (2) lack of agreement among various knowledge disciplines about the applicability and use of ontologies; (3) Lack of cooperation among different educational programs."

Use of Ontology

There was high agreement about compelling evidence of ontology benefits (Q14), with most respondents saying that they are already here or will be within 10 years.

While "International Standards are regularly being developed and expressed, BOTH in a natural language and as an ontology" (Q10) within 10 years, "It is just starting now, it will start as a trickle and take quite a while before it is regular practice," commented one respondent.

Similarly, "ontology-enabled" applications emerge within 5 to 10 years (Q13). Some examples include: (1) Use of ontologies in the healthcare industry (clinical and research) (2) Use of ontologies in the service industry (3) Use of ontologies in the engineering and manufacturing industry.

Ontology Repositories are already available and will be even more so within the following few years. A respondent clearly outlined the developments which might help this to happen:

(1) Maturity of cloud computing and software-as-a-service (2) Compelling use of multiple ontologies to model different aspects associated with problem-solving across heterogeneous knowledge domains (3) Compelling use of ontologies to solve complex and relevant instance of the data interoperability problem.

Funding

Respondents seem to have little confidence that R&D funding will be adequate. Only 9 respondents believe that funding will happen within 2 to 10 years. (Q15)

Breakthrough

There was high confidence that a major breakthrough will happen in the field of ontology within 5 to 10 years.

The Responses

THE FOLLOWING TABLE SUMMARIZES THE PARTICIPANTS' TIMEFRAME ESTIMATES (THE NUMBERS IN PARENTHESIS SHOW THE NUMBER OF PARTICIPANTS THAT ESTIMATED THE DEVELOPMENT OCCURRING IN THE RESPECTIVE TIMEFRAME):

	Development	Timeframe
1	On a global basis, at least 10 universities have an Ontology Science department.	WHAT IS YOUR TIME ESTIMATE FOR THIS TO HAPPEN? here now (please explain) (0) within 2 years (1) 2-5 years (2) 5-10 years (5) 10-20 years (4) beyond 20 years (1) never (please explain) (10)
2	On a global basis, at least 10 universities have an Ontology Engineering department.	WHAT IS YOUR TIME ESTIMATE FOR THIS TO HAPPEN? here now (please explain) (0) within 2 years (0) 2-5 years (2) 5-10 years (5) 10-20 years (3) beyond 20 years (0) never (please explain) (10)
3	On a global basis, at least 10 universities have cross-disciplinary programs in Ontology Science and/or Engineering department offering Master degrees (for career professionals) or PhD degrees (for researchers).	WHAT IS YOUR TIME ESTIMATE FOR THIS TO HAPPEN? here now (please explain) (1) within 2 years (2) 2-5 years (4) 5-10 years (7) 10-20 years (5) beyond 20 years (0) never (please explain) (2)

	Development	Timeframe
4	At least 5% of all professionals in system architecture, systems design and engineering, software engineering and information technology will be required to have proper ontology training (and a larger number will need some background in ontology).	WHAT IS YOUR TIME ESTIMATE FOR THIS TO HAPPEN? here now (please explain) (0) within 2 years (2) 2-5 years (1) 5-10 years (10) 10-20 years (1) beyond 20 years (1) never (please explain) (2)
5	Accredited programs are available from educational institutions that train certified professional Ontologists (with the kind of standings that other professionals like scientists, engineers, architects, lawyers, doctors, nurses, pharmacists, etc.)	WHAT IS YOUR TIME ESTIMATE FOR THIS TO HAPPEN? here now (please explain) (0) within 2 years (1) 2-5 years (4) 5-10 years (1) 10-20 years (7) beyond 20 years (1) never (please explain) (2)
6	The terms and the disciplines of "Formal Ontology" and "Ontology in Information Science" are properly understood by academia and industry (in related fields).	WHAT IS YOUR TIME ESTIMATE FOR THIS TO HAPPEN? here now (please explain) (0) within 2 years (5) 2-5 years (1) 5-10 years (8) 10-20 years (0) beyond 20 years (1) never (please explain) (2)
7	The "ontology" word, and teaching of the basics of it, shows up in secondary/high school education.	WHAT IS YOUR TIME ESTIMATE FOR THIS TO HAPPEN? here now (please explain) (1) within 2 years (2) 2-5 years (1) 5-10 years (2) 10-20 years (2) beyond 20 years (4) never (please explain) (4)

	Development	Timeframe
8	The "ontology" word, and teaching of the basics of it, shows up in primary/elementary school education.	WHAT IS YOUR TIME ESTIMATE FOR THIS TO HAPPEN? here now (please explain) (0) within 2 years (0) 2-5 years (1) 5-10 years (0) 10-20 years (3) beyond 20 years (5) never (please explain) (7)
9	The discipline of "Ontology" is properly understood by everyday people (the way disciplines like mathematics, physics, psychology, music, art, etc. are understood).	WHAT IS YOUR TIME ESTIMATE FOR THIS TO HAPPEN? here now (please explain) (0) within 2 years (0) 2-5 years (1) 5-10 years (2) 10-20 years (4) beyond 20 years (4) never (please explain) (5)
10	International Standards are regularly being developed and expressed, BOTH in a natural language and as an ontology.	WHAT IS YOUR TIME ESTIMATE FOR THIS TO HAPPEN? here now (please explain) (1) within 2 years (1) 2-5 years (2) 5-10 years (8) 10-20 years (4) beyond 20 years (0) never (please explain) (0)
11	Persistent repositories of quality ontologies are available for professional and public use (and they are being regularly used).	WHAT IS YOUR TIME ESTIMATE FOR THIS TO HAPPEN? here now (please explain) (2) within 2 years (2) 2-5 years (5) 5-10 years (6) 10-20 years (1) beyond 20 years (0) never (please explain) (0)

	Development	Timeframe
12	Compelling tools that allow everyday data and information to be "ontologized" by everyday people emerge; please suggest what those tools might be.	WHAT IS YOUR TIME ESTIMATE FOR THIS TO HAPPEN? here now (please explain) (0) within 2 years (1) 2-5 years (0) 5-10 years (10) 10-20 years (0) beyond 20 years (1) never (please explain) (3)
13	Compelling "ontology-enabled" applications emerge; please suggest what they might be.	WHAT IS YOUR TIME ESTIMATE FOR THIS TO HAPPEN? here now (please explain) (2) within 2 years (1) 2-5 years (9) 5-10 years (2) 10-20 years (1) beyond 20 years (0) never (please explain) (0)
14	Compelling evidence of the benefits of "Ontology" emerge; please suggest what they might be.	WHAT IS YOUR TIME ESTIMATE FOR THIS TO HAPPEN? here now (please explain) (5) within 2 years (2) 2-5 years (3) 5-10 years (5) 10-20 years (0) beyond 20 years (0) never (please explain) (0)
15	Significant increase (10x the current level or better; assuming current level is non-zero) in R&D funding is put into developing Ontology science and engineering.	WHAT IS YOUR TIME ESTIMATE FOR THIS TO HAPPEN? here now (please explain) (0) within 2 years (1) 2-5 years (4) 5-10 years (5) 10-20 years (1) beyond 20 years (2) never (please explain) (3)

	Development	Timeframe
16	A major breakthrough is made in the field of Ontology.	WHAT IS YOUR TIME ESTIMATE FOR THIS TO HAPPEN? here now (please explain) (0) within 2 years (1) 2-5 years (2) 5-10 years (9) 10-20 years (1) beyond 20 years (0) never (please explain) (3)

QUESTION: 1.ON A GLOBAL BASIS, AT LEAST 10 UNIVERSITIES HAVE AN ONTOLOGY SCIENCE DEPARTMENT.

here now (please explain)	(0)
within 2 years	(1)
2-5 years	(2)
5-10 years	(5)
10-20 years	(4)
beyond 20 years	(1)
never (please explain)	(10)

What is your time estimate for this to happen?

I'm not clear on the definition of ontology science vs. ontology engineering. In either case, I'm not convinced that anyone's purpose is served by an ontology science or ontology engineering department. If such specialized training comes to exist within the university, my guess it would take the form of a concentration within an existing department or a multi-disciplinary program.

Just a hunch

Ontology is not a science but an engineering discipline

I think that a university department should have a broader focus

I think it will be seen as too specialized, and will be taught within a larger discipline.

It is not a big enough subject to warrant this number of departments. Normally ontology (computer science) would be part of a computing department of some sort rather than a department in its own right.

Ontology Science is not big enough. It is part of much bigger things all overlapping, like information modeling, logic, software engineering etc. There are no departments of information modeling, few if any of artificial intelligence, of machine learning. There may be some for computational linguistics. I can much sooner imagine a department for semantic technology than I can of ontology science. Anyway, it is largely not a science, it is a social process.

Computer science departments will do this, if it's done at all.

I think it is debatable as to whether or not ontology is a science or not. If the science is defined by an area of research and discovery that I think ontology does in fact qualify. Certainly as it is applied more in industry as well as academia there will be research questions that need to be answered. I think it will be many years down the road before there are a collection of adequately trained individuals with an interest in academia to build even a few academic ontology science

departments. Additionally there must be a concerted integration with existing computer science departments which is more a political then an administrative issue. Additionally, application in the areas of basic science biological research and medicine means that significant cross disciplinary training will be required in the eventual field of study. Universities will need to define the value proposition for funding such departments and recruiting faculty. In many medical schools faculty numbers or controlled very tightly from a tenure perspective making it difficult to attract faculty to sub divisions that are not clinically involved.

Question: 1.On a global basis, at least 10 universities have an Ontology Science department.

What are the top 3 to 5 things that need to happen to trigger this development (please prioritize by listing the most important ones first)

More recognition of the needs for a separate department, including specialized curriculum and appropriate appointment and promotion of faculty.

Unify general semantics and systems science, both of which are underrepresented in academic senates. Quantify the economics of knowledge exchange among humans in order to justify attention to ontologies. Avoid getting Ontology Science limited to the perspectives of computer science or information science departments.

(1) Many areas of knowledge need to recognize the need of going from semantic-less data to semantic-full data (2) Many areas of knowledge need to recognize the importance of the data interoperability problem (3) Many areas of knowledge need to recognize the importance of the use of ontologies to solve instance of the data interoperability problem

Some departments of Computer Sience has not believed yet in the ontologies; some people in related areas do not take the approach because they think that ontologies is only Computer Science. The first task is educational.

I think that a few universities already have interdisciplinary degrees in ontology (engineering), though I don't think there is yet a dept. Trento's Applied Ontology Lab and perhaps U-Buffalo come closest. Also, I think this should not be phrased as "information science", which smacks of library science. I would use something like "information technology" ontology, which covers computer science, software engineering, and information science. I think a codified (approved) curricula (preferably approved by a scientific body such as IAOA) and strong advocates at the universities will assist. Of course corporate sponsorship of such a dept. would also help.

Industry and government demand for trained ontologists. 2. Clearly defined fields of ontology and ongological engineering as a distinct field from, e.g., data modeling, knowledge representation, logic. 3. Passionate, committed advocates

Create courses design tests determine certification and continuing education requirements

Undermine competing disciplines, including computer science, information systems, information science, informatics, systems engineering, computer and information science, etc.

Have inadequate demand from industry and academia to form such a department for training purposes. 2. Demonstrate that the content for such a course of study is separable and non-overlapping to other disciplines within the University such as computer science and engineering or mathematics. 3. Have enough trained ontologists that are interested in academia and have adequate governmental interest and funding to sustain their research.

1. have a clear differentiation between Ontology as a science (like Physics, Biology or Psychology), and Ontology as a branch of engineering (like electronic engineering, operations research), as well as Ontology as a cross-discipline support service (like project management, accounting), 2. have compelling reasons why it needs to have its own department, and 3. have the right people who are passionate enough (at each of the early adopter universities) to push that agenda.

Better define what an ontology is (and is not), vs. terminology, information model, etc. - further demonstrate the benefits of using ontologies (and the drawback of not using them) - move from ontology as a religion (with its gurus and their followers) to ontology as a science

1. The general public should understand what Ontology for Information Science is and what is its value and applicability. 2. There should be listings of jobs for ontologists or at least some articles on the future need for ontologists, so that potential students have a motivation to study it. 3. There should be some general guidelines for standards and curriculum that universities could use to set up Ontology Science departments.

The same as the group response

Bring ontologies into high schools Bring them into undergraduate studies Then create entire departments for them

Question: 1.On a global basis, at least 10 universities have an Ontology Science department.

What are the key barriers to this development, and what can be done to mitigate each (identified by yourself or others) to accelerate its happening (compared to your time estimate in column 1)

Evolution rate of universities. Can be accelerated by establishing commercial centers for ontology science (already happening) then funding post docs and docs who will evolve the universities.

(1) Silo-like approaches to problem solving (2) Interoperability is not mandatory in certain areas (e.g., new reforms in healthcare quasi mandate the need of having interoperable electronic health records) (3) Lack of mandatory performance and quality metrics associated with certain processes

Political matters. Lack of professors with the interdisciplinary expertise required.

There has to be a strong enough bottom-up demand for trained ontologists, in order to justify the training and provide jobs for those graduating from the programs. 2. There has to be a clear benefit from a program in ontology engineering that cannot be gained from a degree in, say, information systems with a few courses in ontology engineering. 3. In an era of shrinking resources, there needs to be funding for a new academic program.

The biggest issue is that there is no place to adequately train the ontologists that will staff these universities at the present time-a chicken and egg problem. Like any new technology introduced into an existing domain of software engineering, the proof of its value must be shown and return on investment. Good ontology development requires exceptional domain expertise and the tools to construct sound ontology are not generally usable by domain experts therefore limiting their direct input and increasing the necessary time to invest by both the ontologist and the domain expert to develop sound ontology.

Lack of shared conceptualization of what an ontology is - lack of clearly demonstrated benefits of using ontologies - lack of cross-pollinization across ontology-related communities (philosophers, computer scientists, information scientists, domain experts)

Lack of a unified vision for ontologies; too many stakeholders each shoving their own vision.

This whole study is geared toward the Academic community. Yet, the 'grass roots movement' seems to be evolving from current working technologists (in many different disciplines: modeling, sw design, system architecture, database design...), who are actually starting to implement semantic technology. Yet there is a dearth of education for 'working' technologists who want to start implementing ontologies. Is this working group more the beginning of the curve, and the turning of the hockey stick is happening now with 'working ontologists' who won't be going back to school to get their ontology training? And where is their training? &reas_neg

This isn't needed, so that's a pretty significant barrier. It's either a sub-field of computer science or informatics or perhaps library/info science (which one doesn't really matter) or an interdisciplinary field -- in neither case does it warrant a separate uni-level department.

QUESTION: 2.ON A GLOBAL BASIS, AT LEAST 10 UNIVERSITIES HAVE AN ONTOLOGY ENGINEERING DEPARTMENT.

here now (please explain)	(0)
within 2 years	(0)
2-5 years	(2)
5-10 years	(5)

10-20 years	(3)
beyond 20 years	(0)
never (please explain)	(10)

What is your time estimate for this to happen?

It is hard to imagine that universities would consider treating ontology science and ontology engineering separately. There are no universities with both a computer science and a computer engineering department, but many with one or the other with very overlapping goals.

As for the previous questions, I believe a university department should have a broader scope

This topic is too specialized to be the basis of a university department. But there might be courses offered in OE, in CS or Engineering or Philosophy departments.

Same as for Ontology Science. Too specialized.

I agree with the previous responses: the field of ontology is not large enough. Ontologists are only useful if they are also domain experts or software engineers, so a department that trains 'pure' ontologists is probably not a good idea.

Ontology engineering will become a much more widespread and mainstream skill, much like data modeling, but there are no data modeling departments.

Ontology Engineering is not large enough to be a department in its own right. I would expect ontology engineering to be part of a computing department of some sort.

Question: 2.On a global basis, at least 10 universities have an Ontology Engineering department.

What are the top 3 to 5 things that need to happen to trigger this development (please prioritize by listing the most important ones first)

(1) Many areas of knowledge need to recognize the need of going from semantic-less data to semantic-full data (2) Many areas of knowledge need to recognize the importance of the data interoperability problem (3) Many areas of knowledge need to recognize the importance of the use of ontologies to solve instance of the data interoperability problem

Question: 2.On a global basis, at least 10 universities have an Ontology Engineering department.

What are the key barriers to this development, and what can be done to mitigate each (identified by yourself or others) to accelerate its happening (compared to your time estimate in column 1)

(1) Silo-like approaches to problem solving (2) Interoperability is not mandatory in certain areas (e.g., new reforms in healthcare quasi mandate the need of having interoperable electronic health records) (3) Lack of mandatory performance and quality metrics associated with certain processes

QUESTION: 3.ON A GLOBAL BASIS, AT LEAST 10 UNIVERSITIES HAVE CROSS-DISCIPLINARY PROGRAMS IN ONTOLOGY SCIENCE AND/OR ENGINEERING DEPARTMENT OFFERING MASTER DEGREES (FOR CAREER PROFESSIONALS) OR PHD DEGREES (FOR RESEARCHERS).

here now (please explain)	(1)
within 2 years	(2)
2-5 years	(4)
5-10 years	(7)
10-20 years	(5)
beyond 20 years	(0)
never (please explain)	(2)

What is your time estimate for this to happen?

I don't see this happening. But if it did, it should be a collaboration between a philosophy and a CS or engineering dept.

It is my impression that if you want to do a masters of PhD in ontology engineering or science, that is easy enough to do. I suspect there are 20+ such places.

Question: 3.On a global basis, at least 10 universities have cross-disciplinary programs in Ontology Science and/or Engineering department offering Master degrees (for career professionals) or PhD degrees (for researchers).

What are the top 3 to 5 things that need to happen to trigger this development (please prioritize by listing the most important ones first)

(1) Computer scientists become aware of the importance of an interdisciplinary approach to ontology (2) The (interdisciplinary) ontology community consolidates its methodology

(1) Areas of knowledge begin to experience the positive impact associated with the use of ontologies to solve relevant and pressing instances of the data interoperability problem (2) Areas of knowledge begin to experience the positive impact associated with the use of cooperative approaches to problems solving (e.g. collective intelligence) (3) Computational thinking begins to be recognized as a fundamental cognitive skill

1. Need industrial sector to recognize the need. 2. Need the technical community to understand what ontology science/engineering is.

Existing academic departments must be willing, perhaps due to the clarity of demand, to resist the urge to claim the field for themselves. For the above to happen, the current gulf between the world of ontology applications (industry, government, where ever) and the world of theoretical research must be bridged. In the U.S., the many Government organizations making use of semantic technologies, and therefore in need of ontologists and their work, must find ways to make use cases available to research communities.

I think there a cross disciplinary programs even right now, but not yet 10 such. Maybe 5.

I think programs are easier than departments. Still, the same barriers exist as above -- there needs to be bottom-up demand for the people being trained, resources to develop and maintain a new academic program, trained faculty, passionate "change agents."

Question: 3.On a global basis, at least 10 universities have cross-disciplinary programs in Ontology Science and/or Engineering department offering Master degrees (for career professionals) or PhD degrees (for researchers).

What are the key barriers to this development, and what can be done to mitigate each (identified by yourself or others) to accelerate its happening (compared to your time estimate in column 1)

1) different opinions in the ontology community concerning the very nature of applied ontology

(1) Lack of recognition of computational thinking as a fundamental cognitive skill

The field is still very immature. There is no consensus on metrics for quality, for example. How do you grade students objectively, if the experts in the field do not agree on standards for quality.

QUESTION: 4.AT LEAST 5% OF ALL PROFESSIONALS IN SYSTEM ARCHITECTURE, SYSTEMS DESIGN AND ENGINEERING, SOFTWARE ENGINEERING AND INFORMATION TECHNOLOGY WILL BE REQUIRED TO HAVE PROPER ONTOLOGY TRAINING (AND A LARGER NUMBER WILL NEED SOME BACKGROUND IN ONTOLOGY).

here now (please explain)	(0)
within 2 years	(2)
2-5 years	(1)
5-10 years	(10)
10-20 years	(1)
beyond 20 years	(1)
never (please explain)	(2)

What is your time estimate for this to happen?

I see no reason why it should ever be required. It might well turn out to be the case however, and if so no bad thing.

A lot of people are already finding a need/desire for this skill. It will happen, but it will not be soon.

I'd like to think this is the case. It would contribute to clearer thinking and better communication in these areas. My sense is that there is a lot of use/mention and symbol vs. interpretation confusion in these fields, which might be corrected to some extent by the study of ontology.

Question: 4.At least 5% of all professionals in system architecture, systems design and engineering, software engineering and information technology will be required to have proper ontology training (and a larger number will need some background in ontology).

What are the top 3 to 5 things that need to happen to trigger this development (please prioritize by listing the most important ones first)

(1) Agreement of what "Ontology" is, how to apply it, and how to educate learners about it (2) Agreement among various knowledge disciplines about the applicability and use of ontologies (3) Cooperation among different educational programs

Appearance of an application "proving" the benefits of ontology that is showy enough to capture the minds of managers. Visibility of ontology terms and techniques to professionals and those who hire them. Availability of ontology training/certification.

Question: 4.At least 5% of all professionals in system architecture, systems design and engineering, software engineering and information technology will be required to have proper ontology training (and a larger number will need some background in ontology).

What are the key barriers to this development, and what can be done to mitigate each (identified by yourself or others) to accelerate its happening (compared to your time estimate in column 1)

(1) Lack of agreement of what "Ontology" is, how to apply it, and how to educate learners about it (2) lack of agreement among various knowledge disciplines about the applicability and use of ontologies (3) Lack of cooperation among different educational programs

QUESTION: 5.ACCREDITED PROGRAMS ARE AVAILABLE FROM EDUCATIONAL INSTITUTIONS THAT TRAIN CERTIFIED PROFESSIONAL ONTOLOGISTS (WITH THE KIND OF STANDINGS THAT OTHER PROFESSIONALS LIKE SCIENTISTS, ENGINEERS, ARCHITECTS, LAWYERS, DOCTORS, NURSES, PHARMACISTS, ETC.)

here now (please explain) (0)

within 2 years	(1)
2-5 years	(4)
5-10 years	(1)
10-20 years	(7)
beyond 20 years	(1)
never (please explain)	(2)

What is your time estimate for this to happen?

It's not and never will be big enough to have that kind of standing.

It takes more than a couple of years to get from a situation where there is training, to some certification by, or creation of, some accrediting body of similar standing to, say the IET (in UK) or IEEE (US).

Question: 5.Accredited programs are available from educational institutions that train certified professional Ontologists (with the kind of standings that other professionals like scientists, engineers, architects, lawyers, doctors, nurses, pharmacists, etc.)

Column: What are the top 3 to 5 things that need to happen to trigger this development (please prioritize by listing the most important ones first)

Once ontology-related programs have been established as part of accredited educational/professional institutions, and as part of departments with other accredited programs, the next natural step is to apply for accreditation of ontology-related programs. (2) Once recognized professional organizations that issue certificates (e.g., IEEE, ACM, AAAI, etc) acknowledge the need of ontologies across disciplines, they will add it to the corresponding bodies of knowledge that needs to be evaluated

Question: 5.Accredited programs are available from educational institutions that train certified professional Ontologists (with the kind of standings that other professionals like scientists, engineers, architects, lawyers, doctors, nurses, pharmacists, etc.)

What are the key barriers to this development, and what can be done to mitigate each (identified by yourself or others) to accelerate its happening (compared to your time estimate in column 1)

Lack of agreement of what ontologies are and what they can be used for across many disciplines

QUESTION: 6.THE TERMS AND THE DISCIPLINES OF "FORMAL ONTOLOGY" AND "ONTOLOGY IN INFORMATION SCIENCE" ARE PROPERLY UNDERSTOOD BY ACADEMIA AND INDUSTRY (IN RELATED FIELDS).

here now (please explain)	(0)
within 2 years	(5)
2-5 years	(1)
5-10 years	(8)
10-20 years	(0)
beyond 20 years	(1)
never (please explain)	(2)

Column: What is your time estimate for this to happen?

"Ontology" has become a buzz word. Even experts on ontology do not share a common understanding of "ontology". How can we expect other people to properly understand the term?

Question: 6.The terms and the disciplines of "Formal Ontology" and "Ontology in Information Science" are properly understood by academia and industry (in related fields).

What are the top 3 to 5 things that need to happen to trigger this development (please prioritize by listing the most important ones first)

"Ontology in Information Science" is not (yet?) well understood by many people in philosophy departments. Ontology in general is not yet well understood by those in industry (and this even includes many of those who bandy about the word "ontology").

Maturity of the field will trigger this understanding

Formal Ontology needs to demonstrate that it adds significant value to systems development in general, rather than just in niches and specialized fields as at present.

Question: 6.The terms and the disciplines of "Formal Ontology" and "Ontology in Information Science" are properly understood by academia and industry (in related fields).

What are the key barriers to this development, and what can be done to mitigate each (identified by yourself or others) to accelerate its happening (compared to your time estimate in column 1)

Lack of maturity ... the field needs more time to mature ...

The confusion is currently enormous

QUESTION: 7.THE "ONTOLOGY" WORD, AND TEACHING OF THE BASICS OF IT, SHOWS UP IN SECONDARY/HIGH SCHOOL EDUCATION.

here now (please explain)	(1)
within 2 years	(2)
2-5 years	(1)
5-10 years	(2)
10-20 years	(2)
beyond 20 years	(4)
never (please explain)	(4)

What is your time estimate for this to happen?

Secondary schooling should include a good basis for disciplined thinking and should not specialise into a specific subject like this. First people should learn bachelors degree level engineering discipline, build ontology on top of that.

There are much more important subjects to teach.

It is inherently a degree level subject.

Sort of. In high school, way back in the '70s, I had one Social Sclence class ("World History", 9th grade) and one English class ("World Literature", or some such, 10th grade) in which the question of "What exists?" came up and was discussed.
This will move very quickly, and be driven by social media and the semantic web which are moving very fast.

Question: 7.The "ontology" word, and teaching of the basics of it, shows up in secondary/high school education.

What are the top 3 to 5 things that need to happen to trigger this development (please prioritize by listing the most important ones first)

The recognition of Computational Thinking as an important cognitive skill at the same level of mathematical reasoning, comprehension of written materials, scientific reasoning, etc.

Question: 7.The "ontology" word, and teaching of the basics of it, shows up in secondary/high school education.

What are the key barriers to this development, and what can be done to mitigate each (identified by yourself or others) to accelerate its happening (compared to your time estimate in column 1)

Current status of our educational system, which needs improvements of heroic proportions

QUESTION: 8.THE "ONTOLOGY" WORD, AND TEACHING OF THE BASICS OF IT, SHOWS UP IN PRIMARY/ELEMENTARY SCHOOL EDUCATION.

here now (please explain)	(0)
within 2 years	(0)
2-5 years	(1)
5-10 years	(0)
10-20 years	(3)
beyond 20 years	(5)
never (please explain)	(7)

What is your time estimate for this to happen?

I don't see that as an age appropriate skill, or particularly interesting to the average elementary school student. Perhaps I'm underestimating. A more productive approach at for this age group might be to identify and foster the skills underlying ontology building: pattern recognition, analysis skills. Elementary school-age kids would probably love building physical models.

I expect the word "ontology" and fostering ontology relevant skills to appear in elementary education before appearing in secondary education. These are my opinions, not based in hard evidence: A) There is more latitude in what must be taught in elementary school. B) Curriculum for forward thinking skills are often accepted first at the elementary level: computers, mindfulness and meditation, international classroom connections... C) The skills development required for ontology work is (will be) found to be valuable to child/human development and ideally fostered at a young age.

Question: 8.The "ontology" word, and teaching of the basics of it, shows up in primary/elementary school education.

What are the top 3 to 5 things that need to happen to trigger this development (please prioritize by listing the most important ones first)

Same reasons expressed in connection with secondary/high school education

On-line group-sourcing of ontologies would have to become mainstream. Data modeling never turned up in primary/elementary ed (as far as I know), so it is unlikely that ontologies will either.

Question: 8.The "ontology" word, and teaching of the basics of it, shows up in primary/elementary school education.

What are the key barriers to this development, and what can be done to mitigate each (identified by yourself or others) to accelerate its happening (compared to your time estimate in column 1)

Same reasons expressed in connection with secondary/high school education

QUESTION: 9.THE DISCIPLINE OF "ONTOLOGY" IS PROPERLY UNDERSTOOD BY EVERYDAY PEOPLE (THE WAY DISCIPLINES LIKE MATHEMATICS, PHYSICS, PSYCHOLOGY, MUSIC, ART, ETC. ARE UNDERSTOOD).

here now (please explain)	(0)
within 2 years	(0)
2-5 years	(1)
5-10 years	(2)
10-20 years	(4)
beyond 20 years	(4)
never (please explain)	(5)

What is your time estimate for this to happen?

Ontology will continue to be misunderstood in much the same way that philosophy is.

Practitioners in the other disciplines mentioned in the question all occasionally do things that resonate far beyond their special niche: they reveal previously-unknown facts about the world, propose (or prove) fascinating conjectures in abstract domains, or result in beautiful objects that are enjoyed by many. Regrettably, the efforts of ontologists do not often have any such effects. To the outsider, ontology is little more than taxonomy -- a hierarchical arrangement of terms with some attribute labels attached. What needs to be communicated is how hard it is to do ontology well.

Question: 9.The discipline of "Ontology" is properly understood by everyday people (the way disciplines like mathematics, physics, psychology, music, art, etc. are understood).

What are the top 3 to 5 things that need to happen to trigger this development (please prioritize by listing the most important ones first)

Same reasons expressed in connection with secondary/high school education

Everyday people would first have to know what ontology, the sub-discipline in philosophy was. But noone knows that today after 2000 years.

Question: 9.The discipline of "Ontology" is properly understood by everyday people (the way disciplines like mathematics, physics, psychology, music, art, etc. are understood).

What are the key barriers to this development, and what can be done to mitigate each (identified by yourself or others) to accelerate its happening (compared to your time estimate in column 1)

The recognition of Computational Thinking as an important cognitive skill at the same level of mathematical reasoning, comprehension of written materials, scientific reasoning, etc.

QUESTION: 10.INTERNATIONAL STANDARDS ARE REGULARLY BEING DEVELOPED AND EXPRESSED, BOTH IN A NATURAL LANGUAGE AND AS AN ONTOLOGY.

here now (please explain)	(1)
within 2 years	(1)
2-5 years	(2)
5-10 years	(8)
10-20 years	(4)
beyond 20 years	(0)
never (please explain)	(0)

What is your time estimate for this to happen?

ISO 15926 and ISO 18869 (?) already have elements that are defined as a formal ontology.

It is just starting now, it will start as a trickle and take quite a while before it is regular practice. This wording is ambiguous. If "regularly being developed" is true when only 1% of all standards, but for this 1% it is regular mainstream practice, then I change my answer to 2-5 years.

Standards turnaound is typically 5 years. ISO 20022 is most likely to be developed with an ontology layer in next version, which is realistically 5 - 10 years away. The awareness is there now, so this is simply the standards development time lag not a lag in understanding. I'd say we reached understanding in 2009 in this industry.

Working in standards development and use, each year I hear greater numbers of standards developers and system architects expressing the need for formal, machine-interpretable data structures with supporting logic, which I construe to mean "ontology". I know of a few standards development efforts moving along the path toward ontology and two that have ontology as a defined deliverable today.

Question: 10.International Standards are regularly being developed and expressed, BOTH in a natural language and as an ontology.

What are the top 3 to 5 things that need to happen to trigger this development (please prioritize by listing the most important ones first)

After efforts such as CL (ISO Standard), the next step is to show compelling examples of the importance of applying ontologies to solve complex and important instances of the data interoperability problem

Question: 10.International Standards are regularly being developed and expressed, BOTH in a natural language and as an ontology.

What are the key barriers to this development, and what can be done to mitigate each (identified by yourself or others) to accelerate its happening (compared to your time estimate in column 1)

Lack of demonstration of compelling examples of the importance of applying ontologies to solve complex and important instances of the data interoperability problem

QUESTION: 11.PERSISTENT REPOSITORIES OF QUALITY ONTOLOGIES ARE AVAILABLE FOR PROFESSIONAL AND PUBLIC USE (AND THEY ARE BEING REGULARLY USED).

here now (please explain)	(2)
within 2 years	(2)
2-5 years	(5)
5-10 years	(6)
10-20 years	(1)
beyond 20 years	(0)
never (please explain)	(0)

What is your time estimate for this to happen?

There is really a long way to go.

Some might argue this is true now, but I doubt the persistence. Versioning is a big problem, and the quality of the most widely used ontologies is usually low. Betters sales usually trumps better

Question: 11.Persistent repositories of quality ontologies are available for professional and public use (and they are being regularly used).

What are the top 3 to 5 things that need to happen to trigger this development (please prioritize by listing the most important ones first)

(1) Maturity of cloud computing and software-as-a-service (2) Compelling use of multiple ontologies to model different aspects associated with problem-solving across heterogeneous knowledge domains (3) Compelling use of ontologies to solve complex and relevant instance of the data interoperability problem

Recognized, usable evaluation procedures and tools.

A clearer vision of the way forward and funding at a research level to achieve it. I think the vision needs to incorporate the inevitability of multiple ontologies and how you get them to work together.

Question: 11.Persistent repositories of quality ontologies are available for professional and public use (and they are being regularly used).

What are the key barriers to this development, and what can be done to mitigate each (identified by yourself or others) to accelerate its happening (compared to your time estimate in column 1)

(1) Lack of maturity of cloud computing and software-as-a-service (2) Lack of demonstration of compelling use of multiple ontologies to model different aspects associated with problem-solving across heterogeneous knowledge domains (3) Lack of demonstration of compelling use of ontologies to solve complex and relevant instance of the data interoperability problem

QUESTION: 12.COMPELLING TOOLS THAT ALLOW EVERYDAY DATA AND INFORMATION TO BE "ONTOLOGIZED" BY EVERYDAY PEOPLE EMERGE; PLEASE SUGGEST WHAT THOSE TOOLS MIGHT BE.

here now (please explain)	(0)
within 2 years	(1)
2-5 years	(0)
5-10 years	(10)
10-20 years	(0)
beyond 20 years	(1)
never (please explain)	(3)

What is your time estimate for this to happen?

I am not sure what "ontologized" means, but if the question presupposes that everyday people write ontologies, then this will never happen. Writing good ontologies is hard work and requires a lot of skills. (Writing bad ontologies doesn't, but bad ontologies are useless.)

It is unlikely that "everyday people" will ever develop ontologies, any more than they develop data models.

There is a lot of movement in this direction for tech developers; it is gettng much easier. For everyday people, I won't hold my breath.

Question: 12.Compelling tools that allow everyday data and information to be "ontologized" by everyday people emerge; please suggest what those tools might be.

What are the top 3 to 5 things that need to happen to trigger this development (please prioritize by listing the most important ones first)

Recognize that stored program computers, designed to do arithmetic and list processing, are inconsistent with the topology of an ontology. Do not compromise ontology design to avoid the combinatorial explosion problem. Instead, presume general purpose pattern recognition co-

processors. Use object technology (not object-oriented procedural languages) to define situation-responsive, composable and self-composing ontologies. Note that the worth of ontologies extends far beyond information systems. For example, the ISO standards regarding systems engineering, e.g., 15288, do not anticipate ontologies. Ontologies can enable the design of physical systems faster, cheaper and with fewer unintended consequences. Demonstrate the worth of ontology-based systems in contrast to schema-informed systems.

Note: I am reading this statement to mean tools will be able to automatically create ontologies from the analysis of data/knowledge repositories. Given this reading, I do not think this will ever happen for any repository and any domain of knowledge, but there will be niches for which this will be possible. What will trigger this development is the maturity of the field (Ontology) on selected niches of knowledge

Much much better UI needs to happen. Todays ontology tools and wikis are unusable except by people willing to write code, for the most part. Semantic Media Wiki being an example. Halo extensions are trying to improve things, but it will take much more than that. Everyday people don;t think like a good ontoloogist does (thank goodness, what a boring place Earth would be :-))

Question: 12.Compelling tools that allow everyday data and information to be "ontologized" by everyday people emerge; please suggest what those tools might be.

What are the key barriers to this development, and what can be done to mitigate each (identified by yourself or others) to accelerate its happening (compared to your time estimate in column 1)

Current ontologists not interested in non-computer solutions even though intelligence community have been using them for 30 years. Dominance of Cause-Effect thinking in U.S. education system. Lack of education in general semantics and semiotics.

Lack of maturity of the field across several areas of knowledge

Every day people will have to start thinking like ontologists, but that will not happen. UI will have to take two or three more quantum leaps before it is managable and easy to use ontology tools.

QUESTION: 13.COMPELLING "ONTOLOGY-ENABLED" APPLICATIONS EMERGE; PLEASE SUGGEST WHAT THEY MIGHT BE.

here now (please explain)	(2)
within 2 years	(1)
2-5 years	(9)
5-10 years	(2)
10-20 years	(1)
beyond 20 years	(0)

never (please explain) (0)

What is your time estimate for this to happen?

Very ambiguous question. Does ontology-enabled mean the application was unable to exist w/o an ontology approach, or that the ontology was 'merely' very helpful? If you mean the former, I would say 10-20 years because you can do a lot using old technology, just not as well. If you mean the latter, probably the answer is today.

I think that data cleansing and data integration are challenges that ontology could address today, but ontology based tools need to be developed to support this activity.

Question: 13.Compelling "ontology-enabled" applications emerge; please suggest what they might be.

What are the top 3 to 5 things that need to happen to trigger this development (please prioritize by listing the most important ones first)

As demonstrated with Smalltalk (before it was overrun by the object-oriented programming regression) almost every application can be improved significantly in cost of development, cost of sustainment, agility and change proficiency if based on an ontology. The most obvious and important is the Search application in various situations. Pending an ontology and web topology hardware we shall continue to be frustrated and uninformed with the false positive and false negative results of (key word and other) surrogations of information.

(1) Use of ontologies in the healthcare industry (clinical and research) (2) Use of ontologies in the service industry (3) Use of ontologies in the engineering and manufacturing industry

Question: 13.Compelling "ontology-enabled" applications emerge; please suggest what they might be.

What are the key barriers to this development, and what can be done to mitigate each (identified by yourself or others) to accelerate its happening (compared to your time estimate in column 1)

Lack of maturity of the field and lack of "killer apps"

QUESTION: 14.COMPELLING EVIDENCE OF THE BENEFITS OF "ONTOLOGY" EMERGE; PLEASE SUGGEST WHAT THEY MIGHT BE.

here now (please explain)	(5)
within 2 years	(2)
2-5 years	(3)
5-10 years	(5)

10-20 years	(0)
beyond 20 years	(0)
never (please explain)	(0)

What is your time estimate for this to happen?

Since about 2008 participants in the financial services industry have been talking about the importance of semantics, unprompted by this ontologist. Since 2009 they have felt able to use the O word without embarrassment.

Gene Ontology (and related ontologies) provide very compelling evidence.

There is a ton of evidence now, look at the success of the semantic technologies conference? Look at how many ontology jobs there are? The benefits are the same ones people have been talking about for years. Interoperability, software engineering benefits, search, etc.

Ontology makes a significant contribution to the improvement of data quality and data integration.

Question: 14.Compelling evidence of the benefits of "Ontology" emerge; please suggest what they might be.

What are the top 3 to 5 things that need to happen to trigger this development (please prioritize by listing the most important ones first)

Enhanced exchange of knowledge among humans. Enables User to signify concepts then manipulate contents and relationships. Significant reduction of errors and loopholes in federal, state, local legislation and in corporate policy and procedure statements. Reduce the % of larger scale systems projects that fail to meet expectations from current 60% to near zero.

(1) Continue developing the field (2) Continue looking for examples of 'killer-apps' (3) Identify areas where (2) is likely to happen sooner (rather than later)

Most people seem to have a very grandiose idea of what ontology ought to be for. We need to start with the relatively simple stuff.

Question: 14.Compelling evidence of the benefits of "Ontology" emerge; please suggest what they might be.

What are the key barriers to this development, and what can be done to mitigate each (identified by yourself or others) to accelerate its happening (compared to your time estimate in column 1)

Lack of maturity of the field (2) Lack of systematic and consistent searchibg for examples of 'killer-apps' (3) Lack of focus on areas in which we can be successful in finding killer apps sooner (rather than later)

QUESTION: 15.SIGNIFICANT INCREASE (10X THE CURRENT LEVEL OR BETTER; ASSUMING CURRENT LEVEL IS NON-ZERO) IN R&D FUNDING IS PUT INTO DEVELOPING ONTOLOGY SCIENCE AND ENGINEERING.

here now (please explain)	(0)
within 2 years	(1)
2-5 years	(4)
5-10 years	(5)
10-20 years	(1)
beyond 20 years	(2)
never (please explain)	(3)

What is your time estimate for this to happen?

Not going to happen. Instead, ontology development will replace or augment conceptual modeling and data modeling in general. Not different enough.

I don't think more money is necessarily the right answer. Doing the right things would be much more important.

Question: 15.Significant increase (10x the current level or better; assuming current level is non-zero) in R&D funding is put into developing Ontology science and engineering.

What are the top 3 to 5 things that need to happen to trigger this development (please prioritize by listing the most important ones first)

(1) Funding agencies are convinced of the need of ontologies to tackle instance of the data interoperability problem

Question: 15.Significant increase (10x the current level or better; assuming current level is non-zero) in R&D funding is put into developing Ontology science and engineering.

What are the key barriers to this development, and what can be done to mitigate each (identified by yourself or others) to accelerate its happening (compared to your time estimate in column 1)

(1) Funding agencies need to be convinced of the need of ontologies to tackle instance of the data interoperability problem

QUESTION: 16.A MAJOR BREAKTHROUGH IS MADE IN THE FIELD OF ONTOLOGY.

here now (please explain)	(0)
within 2 years	(1)
2-5 years	(2)
5-10 years	(9)
10-20 years	(1)
beyond 20 years	(0)
never (please explain)	(3)

What is your time estimate for this to happen?

I'm not sure there is a major breakthrough to make. I think it is just a long slog of little details.

This is kind of a silly question. I don't think there have been any major breakthroughs so far in ontology science. The breakthroughs that need to happen are in how humans communicate and agree on terms and definitions. Not yet another logic.

Question: 16.A major breakthrough is made in the field of Ontology.

What are the top 3 to 5 things that need to happen to trigger this development (please prioritize by listing the most important ones first)

Adoption of a computer co-processor capable of set theoretic algebra at more than 1000 times faster than computers can do. Ontology development practiced by everyone age 12 and above.

(1) Keep trying to find a killer app within a relevant domain of knowledge (e.g., healthcare)

Question: 16.A major breakthrough is made in the field of Ontology.

What are the key barriers to this development, and what can be done to mitigate each (identified by yourself or others) to accelerate its happening (compared to your time estimate in column 1)

Lack of focus in order to find a killer app within a relevant domain of knowledge (e.g., healthcare)

DEMOGRAPHICS OF THE PARTICIPANTS

Total number of answers, including all questions and suggestions: 352

Gender Distribution Data
Males= 75.00 %
Females= 25.00 %

Employment Distribution Data
Academic= 25.71 %
Private Sector= 28.57 %
Non Profit= 14.29 %
Government Agency= 11.43 %
Consultant= 17.14 %
Other=2.86 %
Total Employment= 100.00 %

Region Distribution Data
Northern Europe= 3.03 %
Western Europe= 6.06 %
North America= 84.85 %
Total Regions= 100.00%

COMMUNIQUÉ: CREATING THE ONTOLOGISTS OF THE FUTURE

Source: http://ontolog.cim3.net/cgi-bin/wiki.pl?OntologySummit2010_Communique

Summary

Increasingly, major national and international projects and systems centered on ontology technology are being developed and deployed by governments and by scientific and commercial organizations. This brings a growing need for ontology expertise and thus for new methods and organizations for the education and training of ontologists. The goal of the Ontology Summit 2010 was to develop a strategy for the education of ontologists. To achieve this goal we studied how ontologists are currently trained, the requirements by organizations that hire ontologists, and developments that might impact the training of ontologists in the future.

The main findings and results of the Ontology Summit 2010 are:

1. There is already a large demand for trained ontologists, and the demand is expected to increase as ontology-based technologies become more successful and as the quantities and number of different types of data continues to expand.
2. There are very few formal training opportunities for ontologists, and they often do not meet the needs of trainees or of those who would hire them.
3. Organizations that want to hire ontologists often have difficulties in identifying qualified candidates since there are so few formal qualifications in ontology, and there is no professional organization that certifies ontologists.

We developed recommendations for the body of knowledge that should be taught and the skills that should be developed by future ontologists; these recommendations are intended as guidelines for institutions and organizations that may consider establishing a program for training ontologists. Further, we recommend a number of specific actions for the community to pursue as a follow-up to the Ontology Summit 2010 that will improve the education of ontologists.

Introduction

Currently, data and information are often siloed, reflecting the fact that these have been collected in ways designed to address narrowly tailored local needs and in the context of specific applications. As a result data is difficult to reuse for new purposes; different bodies of data do not cumulate; and possible benefits of data integration are lost.

Applied ontology is designed to counteract these effects by creating so-called 'ontologies' that are designed to facilitate more effective information exchange through machine-interpretable representations of reality of more global validity and scope. To this end, applied ontologists

develop the theories, methods and formal tools to support the creation, use and evaluation of ontologies.

Ontologies play a central role in the Semantic Web, the Linked Data movement, and in many other technological developments, for example in the areas of semantic services and the semantic enterprise. A variety of ontology-based approaches, loosely grouped under the heading 'semantic interoperability', have come to the fore as potential solutions to critical interoperability problems. Further, technologies that incorporate and rely on ontologies are used to increase transparency both within and across organizations, and to enhance communication not only between computers but also between human beings.

Major national and international ontology projects have been initiated by governmental, scientific and industrial organizations, for example to support exchange of information across scientific, organizational or linguistic boundaries. But the success of such efforts depends on the availability of well-trained ontologists, capable of designing and building the needed representations and of supporting their successful implementation and resultant integration of data and information.

It is already clear that the resultant need for persons with ontology expertise goes far beyond the current availability of appropriately trained personnel. Organizations seeking to hire ontologists often face difficulties in identifying qualified candidates since there is no professional organization that certifies ontologists and very few educational institutions that offer formal education and training in ontology.

Enhanced training of ontologists would at the same time provide a developing body of knowledge not only concerning the techniques of ontology but also concerning important successes and failures. In this way, it would help those working in semantic technology and related fields to recognize where ontology can be successfully used, and at the same time to avoid a variety of characteristic errors -- and resultant project failures -- that have affected ontology initiatives in recent years.

To work effectively, the ontologist must command a specific set of skills, and it is important to examine how formal education and training can help us both to meet the increasing demand for those who have these skills, and to enable project managers to distinguish qualified ontologists from those who simply claim the title.

The goal of the 2010 Ontology Summit was to develop a strategy for a more coherent approach to the education and training of ontologists. Our work builds on the results of previous Ontology Summits (http://ontolog.cim3.net/cgi-bin/wiki.pl?OntologySummit). To achieve our goals we conducted two surveys, a Delphi study, and several panel discussions to address the following questions:

1. How are ontologists currently trained?
2. What abilities do ontologists consider as necessary for their work?
3. What do employers expect from individuals that are hired as ontologists?
4. What are the developments that might impact the training of ontologists in the future?

The responses to these and related questions allowed us to identify a number of different career paths for ontologists as well as the associated knowledge and skills. On this foundation we developed recommendations for the content that should be taught to future ontologists. In the following we will present the results of our findings as well as our recommendations.

Current State of Training -- Opportunities, Requirements, Expected Developments

Our key findings are:

* The demand for ontologists is expected to rise considerably. There is general consensus from the panel of experts that ontology-enabled applications and tools will become ever more widely used in the coming years. The general consensus is that a correspondingly large number of people with adequate ontology education and training will be needed to the tune of 5% of information systems and software engineering professionals, in the 5~10 year time frame.

* There is a large gap between education needs and education availability. Based on the surveys we conducted, only one academic program was identified as devoted to education in applied ontology (a master's program at the University of Buffalo). In addition, we identified 21 programs that offer ontology-centered courses. These are typically masters-level courses that form part of computing programs. The institutions that have been identified as offering at least one course with partial coverage of ontology are located in Belgium, Brazil, Germany, Iran, Italy, Japan, Netherlands, UK, and USA. These results show that some students (mainly in computer science programs) have some exposure to ontology; and that interest in ontology is not restricted to a particular geographic region. However, the main result is that there exists only one academic program devoted to the training of ontologists. As a result, most of those who might consider an ontology career currently have formal training in other fields and must therefore resort to on-the-job or self-directed training in ontology.

* Significant demand for training opportunities for working professionals. We found that most training opportunities exist within academic degree programs -- for example, ontology courses within computer science curricula. However, there is substantial demand for training outside of such contexts, including single courses, professional certification programs, hands-on training with or without certification, and familiarization courses as short as one week. This demand is perhaps best interpreted in conjunction with the fact that the majority of respondents who expressed an interest in training already have some level of familiarity with ontology and indicate that their interest in the field grows out of their current work.

* Available training opportunities for professionals do not meet needs. Logic and formal semantics are identified as a requirement for ontologists by potential employers, evaluators, working ontologists, and potential trainees. Typically, these subjects are covered in academic programs, however, they are not included in shorter-duration training programs offered to working professionals. There is therefore a significant need for more substantial training programs, delivering not just familiarity but also technical competence, offered in a way that makes them accessible also to those not pursuing an academic degree.

* Important subjects are absent from existing curricula. Experienced, working ontologists, potential trainees, potential employers, professional collaborators, and senior professionals who manage, lead, evaluate and depend upon ontologists identified a number of important subjects that are largely absent from existing curricula.

* Ontology is interdisciplinary. The surveyed ontology experts expect ontology education to take place in interdisciplinary programs. Further, they themselves come from a considerable variety of backgrounds, and they consider their non-ontology training as relevant for their ontology-related work. These results suggest that there is much to be gained by designing curricula that incorporate contributions from multiple disciplines and welcome students from multiple backgrounds, in contrast to focusing more exclusively on just a few feeder fields or departments.

* Employers cannot easily recognize qualified ontologists. Because of the small number of designated programs for ontologists most people working in the field have no formal qualification in ontology. Further, there does not exist a professional organization that certifies ontologists. Because of the lack of formal qualifications, institutions that intend to hire ontologists often have difficulties in identifying qualified candidates.

More details on the surveys:

Education of ontologists: http://ontolog.cim3.net/cgi-bin/wiki.pl?OntologySummit2010_PresentContent_Synthesis#nid25FP

Requirements for ontologists: http://ontolog.cim3.net/cgi-bin/wiki.pl?OntologySummit2010_PresentRequirements_Synthesis

Future developments: http://ontolog.cim3.net/cgi-bin/wiki.pl?OntologySummit2010_FutureDevelopments_Synthesis#nid25HJ

Recommendations for the training of ontologists

Based on our findings we present a list of the knowledge that a student should be taught and the skills that should be developed in an ontology program. Since ontology is a highly interdisciplinary field, it is unrealistic to expect students to learn everything that might be relevant. For this reason, one could characterize our task as being one of identifying the most important knowledge and skills that an ontologist needs to do his job. How this content should be taught is beyond the scope of this document -- this is something that needs to be decided by each individual educational institution on the basis of available resources. At least some of the content is likely to be covered by existing courses in other programs (e.g., in computer science, information studies, or philosophy). We stress, however, that benefits accrue from the maximal possible degree of coordination and of shared content between those offering ontology training programs.

One challenge in creating recommendations for the education of ontologists is that ontology is a young discipline and thus has as yet no widely agreed upon body of shared knowledge, established methodologies, or a common terminology. Instead, multiple terminologies are used in the different subfields of ontology, - for example, deriving from specific programming environments, from database design and the conceptual modeling community, or from traditional philosophical ontology. This is a large obstacle for communication between ontologists and the users of ontologies, and we strongly recommend that all ontologist training programs include terminology survey modules designed to familiarize trainees with these multiple terminologies.

Another challenge is that the careers of ontologists are diverse, as seen from the following examples.

IT-oriented ontologists are actively engaged in the deployment of IT systems involving many components in addition to the ontology itself. For these ontologists it is essential to know how to integrate the ontology into the associated applications. For this purpose ontologists need some background in software engineering, information systems design, system development, object-oriented programming, and data analysis.

Community-oriented ontologists specialize in developing ontologies within a given domain in collaboration with experts from diverse communities. One of their main tasks is to facilitate the resolution of ambiguities in such a way as to build consensus within these communities. To fulfill this role, ontologists need not only to know the scientific area covered by the ontologies (e.g., protein biology or infectious disease), but also need to possess the human-oriented skills that enable them to lead teams of domain experts or to build communities that will support the effective use of ontology resources.

The core knowledge and skills that we list below cover the basics any ontologist will need. They are not of themselves sufficient to support a career as an ontologist; this will require either some additional background in systems development or domain specific knowledge in a relevant application environment.

There is a strong consensus within the community that although much academic knowledge is relevant for ontologists, many important skills cannot be learned from lectures alone. Any education of ontologists has to involve hands-on training in the development and application of ontology. Ideally, academic programs should offer their students the opportunity to gain some of this experience by participating in projects that apply of ontologies to the solution of real and complex problems.

In the following, we distinguish between skills (the ability of a student to do something) and knowledge (basic notions grasped). Since skills build on knowledge, they must be taught together. Because the careers of ontologists are diverse, it is not realistic to develop a single curriculum that fits all students. In the following we distinguish between core and elective skills and knowledge. The idea is that any student should be required to gain all of the core and some of the elective skills and knowledge.

Core Skills

Abilities required for developing, improving ontologies, and applying ontologies:

1. Clarifying the purpose of a given ontology, understanding potential deployment, performing requirements analysis
2. Analyzing existing legacy models and data that are relevant to a given project
3. Judging what kinds of ontologies are useful for a given problem (including: know when ontologies are not useful)
4. Managing ontologies across their life cycle (requirements analysis and planning, managing a systematic update process, versioning, documentation, help desk ...)
5. Identifying, evaluating and using software tools that support ontology development
6. Choosing the appropriate representation language
7. Choosing the appropriate level of detail
8. Identifying existing content resources (e.g., existing ontologies, terminologies and related resources; relevant data; domain expertise, ontology expertise)
9. Assembling an ontology from reusable modules
10. Using (reading, writing) different representation languages
11. Conducting ontological analysis, that is identifying entities and relationships; formulating definitions and axioms
12. Evaluating and improving ontologies (finding errors via manual term-by-term inspection, solving interoperability problems, decomposing large ontologies into interconnected modules)
13. Documenting ontologies (e.g., providing natural language definitions and providing concise explanations for axioms)
14. Working in teams, including those which support the distributed development of ontologies
15. Using at least one modern programming/scripting language

Elective Skills

1. Coordinating ontology development efforts
2. Creating meaningful visualizations of ontology structure for human beings
3. Training people in the use of ontologies

Core Knowledge

1. The basic terminology of ontology (relation of ontology to knowledge representation, conceptual modeling, data modeling, ...)
2. Theoretical foundations
    1. first-order logic, basics of description logic, modal logic, and second-order logic

    2. set theory
    3. basic notions of philosophical ontology (universals and particulars, mereology, essence and identity, unity and plurality, dependence, change in time...)
    4. philosophy of language (the use-mention confusion, sense and reference, speech act theory, ...)
    5. knowledge representation, conceptual modeling, data modeling; metadata
3. Representation languages Part 1: RDF, OWL; Common Logic
4. Building and editing ontologies
    1. human aspects (application of classification principles, manual auditing, ...)
    2. software tools (Protégé, ...)
    3. addressing interoperability problems among ontologies
5. Ontology evaluation strategies and theories (Ontoclean, ...)
6. Examples of ontologies, illustrating different methodologies
    1. upper-level ontologies (BFO, DOLCE, SUMO, ...)
    2. mid-level, domain-spanning ontologies (PSL, ...)
    3. domain ontologies (GO, Enterprise Ontology, ...)
7. Examples of ontology applications (successes and failures)
    1. as controlled vocabularies / standards, to achieve coordination among humans
    2. to solve interoperability problems among external data resources
    3. reasoning with ontology content
    4. improve search and retrieval
    5. Natural language processing
    6. decision support, situational awareness, information fusion, anomaly detection
8. Ontology and the Web
    1. general foundations (URIs, XML, etc.)
    2. Semantic Web initiative
    3. semantically enhanced publishing, literature annotation, data curation

Elective Knowledge

Underlying and related disciplines

1. 1. Advanced logic (modal logic, temporal logic, default logic, ...)
2. Advanced philosophical ontology (mereotopology, tropes, ...)
3. Computer science
    1. formal languages, formal machines, computability, complexity
    2. automated reasoning
    3. database theory
    4. artificial intelligence
    5. logic programming
4. Linguistics / cognitive sciences
    1. distinction between syntax, semantics, and pragmatics
    2. natural language processing, natural language generation
    3. cognitive theories of categorization

Supporting tools, technologies and methodologies

1. Representation languages Part 2 (SWRL, RIF, SKOS; OBO; UML; E-R, IKL, ...)
2. Ontology content acquisition (role of text mining, ...)
3. Achieving ontology interoperability
4. Principles for building ontology repositories
5. Usability and user interface issues (visualization / usability, principles of meaningful arrangement, ...)

Application domains

Any domain could be an application domain for ontologists. Ontologies are already used and are being developed for use in many domains, including science, medicine, business, government, military, education and culture.

Towards Better Education and Training of Ontologists

This document identifies the skills and knowledge a student should possess after successfully completing an ontology program. These recommendations are based on extensive studies of the current training situation, the requirements ontologists face, and the developments that might impact the situation of ontologists in the future.

To improve the training situation in applied ontology we recommend the following actions:

- While the list of requisite knowledge and skills for ontologists above is a valuable first step, it is desirable to describe each knowledge area and each skill in more detail.
- We recommend the development of a registry, allowing members of the community to add information about ontology-centered educational and training initiatives.
- We recommend including more ontology-related content into model curricula for computer science (e.g., those of ACM/IEEE http://www.acm.org/education/curricula-recommendations).
- The requirements survey revealed a surprising non-alignment between the training available to ontologists and the kind of training they need. As the field of ontology continues to evolve and training demand shifts in tandem, we recommend conducting similar surveys at regular intervals. This will enable training providers to ensure that their courses meet the needs of their students.
- Applied ontology has no accepted body of shared knowledge, techniques, and criteria for evaluation. It is in part for this reason that so few ontology training programs in universities have been developed. We recommend taking advantage of the need for trained ontologists, and thus for improved ontology training, as an argument for investing effort in establishing the requisite shared body of knowledge.
- We recommend the creation of a wiki to collect descriptions of case studies demonstrating the importance of certain ontology engineering decisions. These might include examples of bad decisions, the problems they caused, the associated costs, and how the problems were corrected.

Most importantly, we strongly encourage educational institutions to establish programs that address the growing need for ontologists based on the guidelines set forth in this document.

BACKGROUND ON ONTOLOGY

Excerpt from: "What are Ontologies" <http://ontolog.cim3.net/OntologySummit/2012/ontology.html>

Over the past 30 years, as we've come to rely on an ever increasing web of socio-technical systems, we've encountered a slew of new problems. Organizations found that as employees retired or left, their knowledge would leave with them, and in many cases it would cost large amounts of money to maintain or evolve these systems. Similarly, people found that combining two systems was no trivial task. Often, implicit assumptions made by the different designers would contradict one another, making integration impossible. When machines need to talk to one another, or when we want to understand or use a system designed by another person (who might no longer be around), then those implicit assumptions suddenly matter a lot.

A fundamental task for ontology today is to make explicit the implicit assumptions that people or systems make about their relevant portion of the world. This can range from users independently, yet collaboratively creating tag clouds, to search engines providing directories or taxonomies, to organizations developing controlled vocabularies, deploying thesauri and to creating logical models of the world. This makes what we believe accessible to others in a clear, precise way. Forcing us to consider our basic assumptions and bringing to light any subtle disagreements or indeed errors.

In this sense, we engineer ontologies that represent aspects of reality for a particular purpose. The word "ontology" has been used to refer to a wide range of computational artifacts of varying complexity, ranging from folksonomies (tag clouds), controlled vocabularies, taxonomies (Yahoo! directory), thesauri (Wordnet) to logical theories of reality (Basic Formal Ontology, DOLCE).

As Leo Obrst explained in the 2007 Ontology Summit:

> *An ontology defines the terms used to describe and represent an area of knowledge (subject matter).*
>
> *An ontology also is the model (set of concepts) for the meaning of those terms.*
>
> *An ontology thus defines the vocabulary and the meaning of that vocabulary.*

One of the most successful applications of ontologies has been in Apple's Siri. When you ask Siri "find me a restaurant", it activates a "Restaurant Ontology" which defines what a "restaurant", "reservation" and "rating" are and how they're related to one another. Siri uses this information to interact "intelligently" and book you that reservation. IBM's Watson also a number of used lightweight ontologies to distinguish between "people," "places," "times" and other categories when playing Jeopardy!

As our world becomes more complex, ontologies are a vital piece of a solution addressing the problems of Big Systems and Big Data. Depending on the intended use, ontologies can:

- make explicit and accessible, implicit yet vital assumptions about our systems
- enable integration among systems and data through semantic interoperability
- improve model design, adaptability and reuse,
- reduce development and operational costs
- enhance decision support systems
- aid in knowledge management and discovery
- provide a basis for more adaptable systems

Finally, as we move into the knowledge age there is a growing expectation that our systems will be more self-describing and intelligent. In order to engineer such systems, allow intuitive use and meet expectations of all stakeholders, a more consistent and complete use of ontologies and ontological analysis must be made. The 2007 Ontology Summit <http://ontolog.cim3.net/cgi-bin/wiki.pl?OntologySummit2007> provides a more thorough (and somewhat more technical) perspective on the exact nature of ontologies.