The 2006 Upper Ontology Summit Joint Communiqué

Leo OBRST[1], Patrick CASSIDY[1], Steve RAY[2], Barry SMITH[3],
Dagobert SOERGEL[4], Matthew WEST[5], Peter YIM[6]
[1]MITRE, [2]US National Institute of Standards and Technology,
[3]State University of New York at Buffalo, [4]University of Maryland, College Park,
[5]Shell International Petroleum Company, [6]CIM3

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Abstract. On March 14-15, 2006,at the US National Institute of Standards and Technology (NIST) in Gaithersburg, MD there took place the first Upper Ontology Summit (UOS). This was a convening of custodians of several prominent upper ontologies, key technology participants, and interested other parties, with the purpose of finding a means to relate the different ontologies to each other. The result is reflected in a joint communiqué, directed to the larger ontology community and the general public, and expressing a joint intent to build bridges among the existing upper ontologies in ways designed to increase and rationalize their utilization and to enhance their semantic interoperability. The Upper Ontology Summit was sponsored by NIST, Ontolog, the National Center for Ontological Research (NCOR), MITRE, and many other organizations. The UOS was organized by a committee consisting of Pat Cassidy, Peter Yim, Steve Ray, Dagobert Soergel, and Leo Obrst.
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Introduction

On March 14-15 in Gaithersburg, MD, at the US National Institute of Standards and Technology (NIST), the Upper Ontology Summit (UOS) took place (UOS 2006). The Upper Ontology Summit convened the custodians of several prominent upper ontologies, key ontology technology participants, and interested other parties, with the purpose of finding a means to relate the different ontologies to each other. The result is reflected in a joint communiqué, addressed to the larger ontology community and to the general public, and conveying the joint intent of the signers to build bridges among the existing upper ontologies, to increase and rationalize their utilization and to enhance their semantic interoperability. The Upper Ontology Summit was sponsored by NIST, Ontolog, the National Center for Ontological Research (NCOR), MITRE, and many other organizations. The UOS was organized by a committee consisting of Pat Cassidy, Peter Yim, Steve Ray, Dagobert Soergel, and Leo Obrst.

1 Purposes of the Upper Ontology Summit

The Summit was convened to realize two goals. First, to develop the mechanisms and resources needed to relate existing upper ontologies to each other in order to increase the ability to reuse the knowledge to which they give access and thereby facilitate semantic interoperability among those other ontologies that are linked to them. Second, to make the world aware that the technology of upper ontologies has developed to a point suitable for commercial exploitation.

The UOS was organized by a committee consisting of members from the Ontolog community and NIST, and was structured as a public panel discussion for March 15th, 2006, at NIST as part of its Interoperability Week (NIST Interoperability Week 2006), and ending with a proclamation of a joint communiqué by the UOS convenors.

The purpose of this panel was to bring together those who recognize the value of publicly available upper ontologies, and in particular, the *custodians* (developers or maintainers) of the public versions of existing upper ontologies, to find a way to interrelate those ontologies. The intent of the summit was to bettter understand the various positions of the upper ontologies, and work towards possibly providing freely available common ontologies compatible with many of the starting upper ontologies and having sufficient detail to precisely specify meanings of terms and concepts in a broad range of domain ontologies.

The following upper ontologies were represented at the Summit:

Basic Formal Ontology (BFO)
Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE)
Generalized Upper Model (GUM)
Lifecycle Integration of Process Plant Data Including Oil and Gas Production Facilities
OpenCyc
Process Specification Language (PSL)
Suggested Upper Merged Ontology (SUMO)

2 The Technical Problem Addressed

The main problem motivating the convening of this conference has been discussed with increasing frequency in recent years, namely that knowledge expressed in one formal ontology cannot usually be reused accurately in another formal ontology without 1) a syntactic conversion of the formal representation from one ontology to another; 2) resolving the expressivity issues between the knowledge representation languages that the two ontologies are expressed in; and 3) resolving the semantic differences between the two ontologies, i.e., their potentially distinct ontological assumptions and hence ontological commitments, and their particular philosophical stances on what objects ontologies represent and how those objects can be represented. This lack of 'semantic interoperability' effectively makes unavailable many existing resources for those building knowledge-based systems. It also retards the development of effective knowledge-based systems by reducing the ability of developer groups to take advantage of the difficult and time-consuming efforts by which other teams of developers have succeeded in solving one or another aspect of the multifaceted problem of reasoning with complex information.

The issue of mediating among the different syntactic forms and expressivities of the representations (e.g., the Web Ontology Language OWL [Bechhofer et al 2004] versus the Knowledge Interchange Format KIF or Common Logic) has been actively addressed in individual studies and conferences. Conversion of ontology content (semantics) even if represented in the same language is more complicated than conversion of formats, because the various separately developed ontologies tend to define their more general terms in subtly different ways, which do not correspond exactly to the sets of combinations available in other ontologies, and often reflect very different ontological assumptions.

Upper ontologies present special problems of daunting complexity because of the greater level of abstraction and greater detail in the concepts expressed. The higher abstractions, removed from the world of immediate sensory experience, create a greater likelihood that the logical forms of such concepts will differ among the different upper ontologies in ways that cannot be compared accurately to each other without creation of additional bridging concepts, or even of higher levels of abstraction. This difficulty of comparing the logical forms propagates down to those specialized ontologies whose concept representations are linked to and specified using the elements of the upper ontologies at issue.

This meeting was organized to discuss whether and by what mechanism effective relations among the existing upper ontologies can be discovered, discussed, and potentially resolved, so that knowledge represented using any one of the existing ontologies can be accurately converted into terms derived from the others.

Three potential methods were considered to achieve the desired relations: 1) merge the upper ontologies; 2) create a simplified upper ontology, a compatible subset of all of the linked upper ontologies, which we will term the Compatible Subset Upper Ontology (CSUO); or 3) align the upper ontologies by creating mappings or inter-ontology relations among them. The cooperation of the upper ontology custodians towards this effort is essential, since it is likely that to achieve a CSUO, a merged upper ontology, or a set of mappings, some modifications to one or more of the existing upper ontologies will be required. The feasibility of any of these approaches is most likely to be demonstrated as a result of a substantial effort including several of the Upper Ontology custodians. Although some of us consider (1) a merged upper ontology rather less likely to be realized than (2) CSUO or (3) mappings, we list all three alternatives for completeness.

3 UOS Deliverables and Deadlines

One month prior to the March 15th Upper Ontology Summit meeting the custodians (developers and maintainers) of the participating public upper ontologies began discussion of the goals for the meeting and the method to prepare for the meeting. Consensus was largely reached prior to the meeting to announce an agreement at the meeting in the form of a joint communiqué. The communiqué is an agreement in principle to pursue some method to interrelate the existing upper ontologies so as to encourage creation of ontologies that can be imported or converted into one or more of those upper ontologies.

The announcement was made by a panel of custodians at a meeting open to the public and to the press. The communiqué was signed by the upper ontology custodians, and endorsed by key participants, co-organizers, as well as other key potential adopters of the

work product from this agreement.

4 Events of the Upper Ontology Summit

The possible areas of agreement were discussed among the panelists prior to the public March 15th meeting through a specially convened Ontolog distribution list (UOS 2006). On March 14th, a meeting of the custodians, key participants, and the organizers was held at NIST to solidify the consensus concerning the content of the communiqué to be issued at the conclusion of the summit by resolving any remaining contentious issues.

At the March 15th meeting, this joint communiqué by the convenors of the UOS was announced publicly. It declared that the upper ontology custodians and the key participants would work toward some means of interrelating their ontologies to provide a convenient means for users to rapidly develop knowledge bases that can be used with reasoning tools compatible with any of the existing upper ontologies.

Another suggested goal of the UOS was to develop agreement among developers of mid-level and upper-mid-level domain-spanning ontologies to use a Compatible Subset Upper Ontology (CSUO) as the common high-level ontology that would serve as the common reference ontology for specifying meanings. This goal ultimately did not gain full consensus by the convenors, though it was agreed to by custodians of several of the upper ontologies represented at the meeting.

March 14 Upper Ontology Summit Session

The first day's session focused on confirming the points of agreement, highlighting the disagreements, describing challenges and opportunities, and discussing prospective technical and programmatic next steps of the convenors following the signing of the communiqué. The general questions for the day were the following.

4.1.1 General Questions

What do we agree on? We desire semantic interoperability among upper ontologies and agree that a typical subclass taxonomy would be insufficient for accomplishing that. We agree that axioms are ultimately an indispensable part of creating semantic interoperability, but suggest that less formal methods such as giving verbal definitions may help too. We agree to disagree on the best way to achieve semantic interoperability: establishing (partial) alignments/correspondence, creating a common subset, merging the ontologies, or creating a common upper ontology. We agree that the best combination of mechanisms may emerge from the work to be undertaken, and that the dialog on making upper ontologies interoperable will contribute to improvements in the existing upper ontologies.

In addition to this foundational question, many other questions were put on the table for future resolution:

How do we achieve modularity and handle incompatibilities? Do we develop an approach using a lattice/poset of theories (Sowa 2006)? How do we reconcile a 3-dimensional and a 4-dimensional analysis?

What are the methods to map among the terms/axioms of the relevant upper ontologies? Do we develop term-to-term maps, bridging axioms, find consistent common interpretation subsets? Do we develop a reference library of upper ontologies? Should we express the upper ontologies in a common language such as Common Logic (CL) Interchange Format (CLIF) or the Interoperable Knowledge Representation for Intelligence Support (IKRIS) Knowledge Language (IKL) ?

Do we need a common language for expressing commonalities and differences, such as points of intersection, areas where agreement is easy vs. areas where agreement would be difficult, i.e., barriers to agreement, e.g., assumptions on which ontologies are based. Should we seek agreement on what needs to be defined, rather than reach agreement on definitions? Should we develop a meta-ontology or define a common working vocabulary for expressing the meaning of the terms in Upper Ontologies, including notions of typing, intension and extension, and concept vs. type, attribute, relation, property, and facet?

What are the criteria for evaluating ontologies, including application-based criteria, methods, protocols and testbeds? Should we consider an ontology certification process? Can we characterize important dimensions such as the competence and coverage in a given ontology, design time vs. runtime aspects, reasoning performance metrics, expressivity vs. efficiency tradeoff, reflection capabilities: reasoning on state of knowledge?

What are the prospective next technical and programmatic steps as a follow-on to the UOS? Should we create a consortium or working group, possibly aligned with an existing standards organization? Can we begin to identify pairs of upper ontologies and/or content elements across upper ontologies where alignment work would be particularly appropriate? What are the opportunities for seeking joint funding to address these issues?

After posing and discussing these questions, the session featured short presentations by the Upper Ontology custodians (physically present or via telephone) on the issues (feasibility, utility, etc.) of the UOS from their perspectives with respect to an interrelated UO, the joint communiqué, and beyond. The custodians consisted of:

Doug Lenat (OpenCyc)
Adam Pease (Suggested Upper Merged Ontology (SUMO))
Barry Smith (Basic Formal Ontology (BFO))
John Bateman and Till Mossakowski (Generalized Upper Model (GUM))
Michael Gruninger (Process Specification Language (PSL, ISO 18629);
Matthew West (ISO 15926)

Nicola Guarino (DOLCE) also presenting Aldo Gangemi's DOLCE Descriptions and Situations Ontology.

Most of the rest of the afternoon focused on discussing the major technical issues raised by the questions of the morning.

4.1.5 Technical and Programmatic Follow-On Activities

The final session of the afternoon of March 14 focused on prospective follow-on activities and a final resolution of the wording of the joint communiqué. Both technical and programmatic follow-on activities were identified, including the authoring of an UOS event summary and issues white paper for prospective publication in the Journal of Applied Ontology. There was discussion about the seeking of potential joint funding opportunities that could continue the UOS goals by enabling mapping, intersecting and/or relating the upper ontologies to each other; organizing for continued activities including prospective alignment with standards organizations or proposals for new standards related to upper ontologies, subsequent meetings of the UOS convenors, and the prospects for a new consortium or working group.

March 15 Upper Ontology Summit Session

The March 15 morning pre-summit session was entitled “Upper Ontology Application Dialog.” After a short period resolving some residual issues concerning the modifications of the communique from the previous afternoon, the morning's agenda proceeded. It began with some of the Upper Ontology custodians presenting case examples of applications employing their respective upper ontologies. The second part of the session included an invited panel and an open discussion among the UO conveners and potential users and stakeholders of upper ontologies.

The afternoon session was the Upper Ontology Summit meeting proper, and was open to the public and the press. It began with a statement of the goals of the UOS. This opening statement was followed by a very general introduction to ontologies and the potential business value of semantic technologies. Having introduced to the audience the notion of ontologies, a second presentation focused on the value of formal ontologies.

The joint communiqué was then presented to the assembly, followed by a series of presentations by the custodian panelists concerning their respective upper ontologies and the issues involved in the communiqué from their individual perspectives.

5 The Upper Ontology Joint Communiqué, March 15, 2006, Version 1.02

(1) The theory and technology of knowledge representation, reasoning and conceptual modeling have advanced to a stage where meanings of terms can be formally specified in computer systems with great detail and precision.

(2) With the success and expansion of the internet, the potential for achieving semantic interoperability across interconnected applications has become widely recognized, and the number of teams and individuals creating knowledge classifications of varying de-

grees of logical formality has dramatically increased. As this technology develops further, it will enable deployment of computer applications with increasing ability to make reliable knowledge-based decisions that currently require human effort. Programs with such enhanced capacity will increase the speed, efficiency, and sophistication of automated information analysis and exploitation.

(3) Much recent emphasis has been focused on creating common syntactic formalisms for representing knowledge, but syntactic formalisms alone do not provide an effective way for describing what counts most: semantic content.

(4) The complementary technology for effectively representing the semantic content of complex widely used concepts is also available, but agreement on standardized conceptual building blocks has not yet been reached.

(5) The need for such agreement is increasing rapidly as many isolated projects of varying complexity have been initiated to capture knowledge in computer-interpretable formalisms. Without the means for specifying intended meaning by means of well-understood conceptual building blocks clearly related and contrasted with each other, the great potential for sharing knowledge usable for computer reasoning will not be realized.

(6) Several candidate upper ontologies are available, reflecting decades of research and development.

(7) Each upper ontology has an existing community of users, but each community only has access to a fraction of the total resources available.

(8) To promote interoperability and the exploitation of these upper ontologies, we intend to find a principled means of articulating the relationships (including differences) among them. As a result, this initiative will significantly enhance the value of the knowledge in each of the communities whose knowledge bases are linked to these interrelated upper ontologies.

(9) These upper ontologies are available and should be rigorously and independently evaluated. They must also be easy to use and assess by developers of domain ontologies and applications.

(10) For the foreseeable future, we anticipate there will be multiple upper ontologies. We will articulate the commonalities and the reasons for the major differences in the upper ontologies.

Hereby unanimously agreed to by the following upper ontology custodians*:*

John Bateman – Generalized Upper Model – GUM	Doug Lenat – OpenCyc

Aldo Gangemi - DOLCE - Descriptions and Situations Ontology	Adam Pease – Suggested Upper Merged Ontology (SUMO)
Michael Gruninger – Process Specification Language (PSL)/ISO 18629	Barry Smith – Basic Formal Ontology (BFO)
Nicola Guarino - Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE)	Matthew West - ISO 15926 - Integration of Life-Cycle Data for Oil and Gas Production Facilities

Endorsed by Upper Ontology Summit participants:

Bill Andersen	Michael Fitzmaurice
Tom Beckman	Richard MacMillan
Denise Bedford	Dave McComb
Gary Berg Cross	Chris Menzel
Conrad Bock	Till Mossakowski
Alan Bond	Mark Musen
Peter Brown	Sergei Nirenburg
Werner Ceusters	Michael Uschold
Mills Davis	Chris Welty

Upper Ontology Summit Organizing Committee:

Pat Cassidy	Dagobert Soergel
Leo Obrst	Peter Yim
Steven Ray	

The official source document of this communiqué can be found at (Joint Communiqué, UOS 2006).

6 The Upper Ontology Summit Convenors and Co-Sponsors

The UOS Organizing Committee members, the Key Public Upper Ontology Custodians, UOS Key Participants, and the UOS organizers are referred to, collectively, as the UOS Convenors.

The Co-Sponsors are organizations who provided technical or funding support, and/or endorsed the purpose of this Upper Ontology Summit. The following were the Co-Sponsors of the UOS.

Upper Ontology Summit Organizing Co-Sponsors:

The Applied Ontology Journal: An International Journal of Ontological Analysis and Conceptual Modeling, http://www.applied-ontology.org/ (Nicola Guarino and Mark Musen)
Boeing - http://www.boeing.com/ (Michael Uschold)
EPISTLE - European Process Industries STEP Technical Liaison Executive, the consortium responsible for the development of ISO 15926 - http://www.btinternet.com/~Chris.Angus/epistle/ (Matthew West)
CIM3 - CIM Engineering, Inc. - http://cwe.cim3.net (Peter Yim)
CNR - Institute for Cognitive Sciences and Technologies, Laboratory of Applied Ontology (Trento and Rome) - http://www.loa-cnr.it/ (Nicola Guarino and Aldo Gangemi)
Cycorp – www.cyc.com (Doug Lenat)
IBM Research - http://www.research.ibm.com/ (Chris Welty)
IEEE Standard Upper Ontology Working Group - http://suo.ieee.org/ (Jim Schoening)
ISO TC 184 SC 4 JWG8 - the ISO working group that developed the ISO 18629 Process Specification Language (PSL) standard - http://www.tc184-sc4.org/SC4_Open/SC4_and_Working_Groups/JWG8/N-DOCS/maindisp.cfm (Michael Gruninger)
MITRE – http://www.mitre.org (Leo Obrst and Pat Cassidy)
NCOR - (US) National Center for Ontological Research - http://ncor.us/ (Barry Smith and Mark Musen)
cBio - The National Center for Biomedical Ontology - http://ncbo.us/ (Mark Musen)
NIST - (US) National Institute of Standards and Technology - http://www.nist.gov/ (Steve Ray)
OASIS UBL TC - the working group developing the XML-based Universal Business Language (UBL) standard (Jon Bosak)

Ontolog - http://ontolog.cim3.net/ (Peter Yim, Leo Obrst, and Kurt Conrad)
Ontology Works, Inc. - http://www.ontologyworks.com/ (Bill Andersen)
Shell International Petroleum Company - http://www.shell.com/ (Matthew West)
Bremen Ontology Research Group at Bremen University, supported by the faculties of Informatics and Linguistics and the Collaborative Research Center for Spatial Cognition - http://www.fb10.uni-bremen.de/ontology/ (John Bateman and Till Mossakowski)
Department of Philosophy, University at Buffalo - http://ontology.buffalo.edu/ (Barry Smith)
UMBC - University of Maryland, Baltimore Campus - Institute for Language and Information Technologies (ILIT) - http://ilit.umbc.edu/ (Sergei Nirenburg)
University of Maryland, College Park, College of Information Studies - http://www.clis.umd.edu/ (Dagobert Soergel)
Stanford Medical Informatics Laboratory – http://www.smi.stanford.edu/ (Mark Musen)
University of Toronto - http://www.utoronto.ca/ (Michael Gruninger)

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DOLCE Descriptions and Situations ontology. http://www.loa-cnr.it/ontologies/DLP_397.owl. See also: http://www.loa-cnr.it/Papers/ODBASE-CONTEXT.pdf.

Generalized Upper Model (GUM). http://www.fb10.uni-bremen.de/anglistik/langpro/webspace/jb/gum/index.htm.

IKRIS. http://nrrc.mitre.org/NRRC/ikris.htm.

Interoperability Week. http://www.mel.nist.gov/div826/msid/sima/interopweek/.

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