Embracing Dynamic Semantics

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The Ontology Management Team

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Introduction

- What is the Ontology Management Team?
- Why care about Semantics?
- What are Semantics? Are we all on the same page?
- What will this presentation cover?

The Ontology Management Team

- OMT is a spin-off of the Ontolog Forum
- Ontolog is an open community
  - http://ontolog.cim3.net/
  - Focused on ontologies used in business
  - Advocates use of ontologies in standards development
- OMT focus
  - Understand factors driving effective management of ontology engineering projects
  - Identify and develop methods to ensure quality and alignment of needed conceptual models
  - Bridge theoretical, problem, and engineering domains

Why Care About Semantics?

- Semantic Technologies assume a foundation of explicitly-formalized semantic models
- As these semantic models become richer, they better reflect the meaning of symbols in the real world
  - Enable targeting of “harder” problems
  - Support more complex, context-sensitive behaviors
  - By separately codifying semantic models (especially rule bases), they can improve maintainability

What Are Semantics?

- What do we mean when we use the term Semantics?
  - Semantics ≈ Associated meaning in a behavioral context
  - Ontology ≈ Semantic Model, Conceptual Model, World View
- Authors take a whole-systems perspective
  - Not just a technology issue
- Semantics are reflected in a wide range of ontologies
  - Artificial and natural
  - Formal, semi-formal, and informal
  - Explicit, implicit, and tacit (unwritten rules)

What will this presentation cover?

- Semantics are naturally dynamic
  - Potential source of problematic destabilizations
  - Potential source of significant opportunities
- MetaKnowledge models provide a framework to isolate critical semantic changes and illuminate appropriate responses
- MetaKnowledge Management
  - Is a compelling strategy for semantic formalization
  - Resolves a number of common gaps and breakdowns
  - “Embraces” Dynamic Semantics

Semantics are Naturally Dynamic

- Dynamic Semantics (DS) results from the interplay of three agent types and their associated ontologies
  - Automated Agents
  - Social Agents
  - Individual Agents
- Each contributes and reacts to DS somewhat differently
- The resulting dynamics create both risks and opportunities for Semantic Technology efforts

Automated Agents

- Machines that can't create meaning
  - Must be informed
  - Dependent on the meanings produced by Social and Individual Agents
- Require explicit Knowledge Artifacts (KAs)
  - Including explicitly formalized semantic models / ontologies
  - Semantic formalization often about making critical properties and/or class distinctions explicit

Automated Agents and DS

- May need to support multiple semantic models
  - Artifacts that enable behavior in multiple contexts
  - Software that functions within multiple contexts
- Potentially destabilized by upstream changes to social and individual ontologies
  - Decreasing alignment through time is an all but certain result of formalization and explicitness

Social Agents

- Organizations, groups, and systems
- It's all about agreement
  - Creation of shared conceptualizations
  - Shared understanding and communication
  - Identification of shared meaning
- Consensus both relatively difficult and relatively stable
- Effective political processes are necessary precursors to effective engineering processes
- …especially the engineering of ontologies!

Social Agents and DS

- Potential for confusion
  - Symbols with multiple meanings (ambiguity)
    - Subtle conceptual differences
    - High levels of implicit Knowledge
  - Use of multiple symbols for the same concept
  - Differing behavioral expectations
    - Scenarios, causal models, sense-making structures, theories
- Subject to competitive pressures
  - Conflicting values, interests, and objectives
  - Power, position, influence
  - Economic market forces

Individual Agents

- Ultimate source of meaning
  - Life is a quest for meaning
  - Death is a profound collapse of meaning
- Meaning can be associated with anything
  - Evolutionary origins of rationality
  - Ability to assess meaning and potential impacts
  - Ability to react, anticipate, predict, even control future conditions and events

Individual Agents and DS

- Leverage multiple operational ontologies
  - Each is optimized to balance potentially divergent values relative to a targeted set of behaviors (multiple roles)
  - Potential for rapid, real-time context switching
- Impact of learning
  - Expands and destabilizes individual ontologies
  - Difficult to avoid

Identifying Dynamic Semantics

- Which agents are involved?
  - Which ones have the capacity to drive semantic change?
  - Do any have a history of driving semantic change?
  - Which ones are likely to be impacted?
- How significant are the changes likely to be? In what timeframes?
- Are the semantic changes likely to be beneficial and/or detrimental? Are they inevitable? Are they reversible?
- How much semantic alignment is needed, possible, advisable, etc.?

Semantics are Naturally Dynamic

- Meaning isn't an inherent property
  - Ultimately the product of human imagination and creativity
- Complex set of mechanisms both drive and limit changes to perceived meaning
- DS ultimately impact automated systems
  - From individuals (changes to conceptualization)
  - From groups (dynamic / evolving consensus)
- Making semantics explicit doesn't necessarily limit or slow upstream change

Analyzing Dynamic Semantics

- While analysis of agents and agent types can be used to identify DS, it doesn't provide enough detail to drive specific responses
- Need more sophisticated models that let us look beyond agent types to specific Semantic Classes and properties
  - Knowledge Artifact Continuum Model
  - Semantic Optimization Model
  - MetaKnowledge Continuum Model

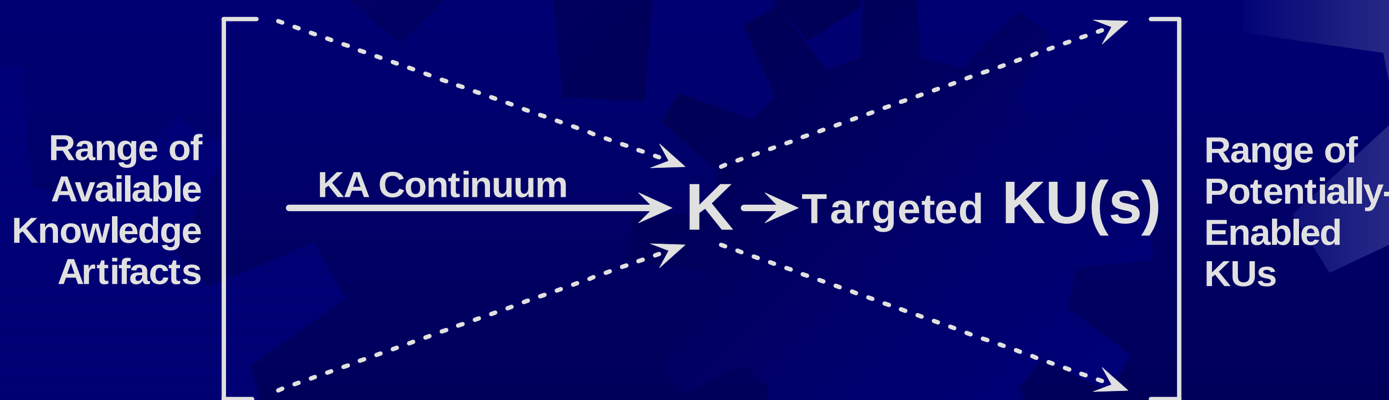
Knowledge Artifact Continuum Model

$$D \; f \; I \; f \; K \Rightarrow KU$$

- Describes a continuum of Knowledge Artifacts
  - Data (D) is transformed (f) into Information
  - Information (I) is transformed into Knowledge
  - Knowledge (K) represents the point of actionable synthesis of all event-specific (K_E) and prior (K_P) knowledge
  - K enables a Knowledge Utilization Event (KU)
  - KU is either an action or a decision
- Boundaries are not necessarily discrete

Semantic Optimization Model

- Knowledge synthesis is optimized around targeted KUs
  - Drives selection of specific Knowledge Artifacts for synthesis
- Reflected in the semantic properties that are available if a Knowledge is codified to create an explicit artifact
  - Points to potential quality measures for Knowledge Artifacts



MetaKnowledge Continuum Model

$$\begin{array}{ccccc} D & f & I & f & K \Rightarrow KU \\ \downarrow & & \downarrow & & \downarrow \\ mD & & mI & & mK \end{array}$$

- Also describes a continuum without discrete boundaries
- MetaKnowledge (MK) comprises a range of KAs
  - Like the generic term MetaData
  - The term MetaKnowledge is used deliberately
- mD, mI, and mK (specific to this model) document
  - Critical semantic properties of each class of KA
  - Knowledge about the transformations that produced them

Semantic Classes

- These models point to the existence of four "distinct" classes of semantic properties
  - Interpretive Semantics
  - Contextual Semantics
  - Aspirational Semantics
  - Behavioral Semantics
- More to come?

Interpretive Semantics

- Deal with the interpretation and meaning of symbols
- Knowledge about how symbols map to concepts
  - Potentially ambiguous (multiple meanings, double entendres)
  - Result of observational and symbol selection behaviors
- Answers the question: What is it?
- Maps to mD in the MK Continuum Model

Contextual Semantics

- Deal with context and pattern recognition
- Knowledge about how KAs (or parts) relate to
  - Transformation and representation behaviors
  - Other KAs
  - The real world
- Answers the questions
  - What kind? What is it about?
  - Who, where, when?
  - How, especially "How does this fit?"
- Maps to ml in the MK Continuum Model

Contextual Semantics Principles

- Appears to be the "first place" that values play a significant role in sense-making
- Meaning often expressed in historical terms that imply future semantics
  - "You always.."
  - "They always…"
  - "It always…"
- Contextual Semantics often implied, incomplete, or missing
  - Supplied by the interpreting agent

Aspirational Semantics

- Deals with underlying motivations, drivers, rationality
- Knowledge about how KAs are synthesized and optimized to enable behavior
- Answers the question "Why?"
  - Infrequently documented
  - Often tacit and implicit
- Individuals provide, when missing
  - Routine source of semantic breakdowns
- Maps to mK in the MK Continuum Model

Behavioral Semantics

- Meaning, as described in behavioral terms
- Often involves complex semantic chains (scenarios) which comprise
  - Events
  - Conditions
  - Other behaviors
- Representations range from tacit to explicit
  - Culture
  - Law

Analyzing Dynamic Semantics

- For each Semantic Class and the specific semantic properties within each class
  - How volatile are the semantics?
  - Is the volatility exhibited or expected?
  - What's driving volatility?
  - Does the semantic volatility have natural or artificial origins?
  - Is it likely to drive specific breakdowns: gaps, disagreements, sub-optimizations, etc.
  - Can you do anything about it?
- Is the volatility desirable and/or valuable?
- Does it point to emergent value propositions?

Addressing Dynamic Semantics

- Ignore semantic volatility
  - Leave critical semantic properties largely implicit and tacit
  - Appropriate for non-critical issues
- Stomp
  - Make semantic properties more explicit
  - Formalize without addressing sources of volatility
  - Good when you can get away with it
- Embrace
  - Understand change vectors
  - Balance explicit, implicit, and tacit representations
  - Implement mechanisms to identify and/or leverage “natural” misalignments as they emerge

MetaKnowledge Formalization

- Identify areas of potential semantic conflict
  - Resolve conflict, as appropriate
  - Integrate semantic models, where each has value
- Avoid sub-optimization around machine-processable semantics
  - Evaluate each Semantic Class for potential value
  - Consciously balance or optimize the explicit representations
  - Document implicit and tacit MK triggers that are only usable by individuals and groups
- Where practical, expand the range of targeted KUs and associated behavioral semantics

Case Studies

- Knowledge Representation
  - Camping List
  - National Health Information Network RFI Response
  - Markup Language Design
  - Researcher's Notebook
  - Compliance Management
- Semantic Alignment
  - Advanced Semantics
  - Semantic Harmonization & Ontological Expression of eBusiness Standards

Camping List

- Context: Family camping trips
- Destabilization vectors
  - Equipment storage: home, packed for transit, camping
  - Context-sensitive editing
- Goal
  - Reflect containership hierarchy in all contexts
- Issue
  - XML encodes a single hierarchy
- Strategy
  - Use XSLT to make Contextual Semantics explicit
  - Use attributes to store Contextual Semantics
  - Use XSLT to switch the hierarchy between contexts

NHIN RFI Response

- Context: $6-12 Trillion sector of the economy
- Destabilization Vectors
  - Knowledge of requestors goals highly dynamic. Largely implicit, including presumed solution(s). Public and private discussions extended through submission deadline.
  - Respondent group comprised volunteers that spanned multiple areas of subject matter expertise. Perceived interests and potential conflicts of interest "churned" participation.
- Goals: Meet deadlines, develop a document that would be well received and acceptable to the authors
- Issue: Unable to drive consensus around all aspects of the response within time limits
- Strategy: Made authorship of portions of the response explicit to Communicated balance between consensus and independent opinions

Markup Language Design

- Context: Content standards for large enterprises
- Destabilization Vectors
  - Lack design guidelines for both old and new models
  - Uncertain utilization scenarios
- Goal
  - Reduce downstream costs from, especially from “relearning”
- Issue
  - Traditional “comments” didn’t guide Knowledge capture
- Strategy: Model Aspirational Semantics
  - Issues, divers, rationale for design decisions
  - Knowledge sources, confidence levels, policy decisions

Researcher's Notebook

- Context: Documenting open-ended research activities
- Destabilization Vectors
  - Research not driven by a single KU
  - New research impacts semantics of old findings
- Goals
  - K transfer across time and among agents
  - Identify new semantics and sense making structures
- Strategy
  - Enable capture across the full range of Semantic Classes
  - Level of effort matched to perceived importance
    - At both time of discovery and later times
    - By original author and by others

Compliance Management

- Context: World-wide operations
- Destabilization Vectors
  - Specific requirements change through time
  - Tracking of revisions and associated analysis
  - Mapping to compliance auditing processes and training
- Goal
  - Use a single XML document for all versions, analysis, mappings
- Issue
  - Which model to use for dominant hierarchy?
- Strategy
  - Structure common to all contexts used as dominant hierarchy
  - Anchor other MK to “smallest revisable units”

Advanced Semantics

- Context: Pilot advanced semantics for large enterprise
- Destabilization Vectors
  - Intentional abandonment of existing semantic models
  - 6 - 12 divergent operational ontologies. Each promoted as “the hub”
  - Fast-paced schedules precluded investment in alignment
- Goal
  - Establish shared conceptual model that will evolve, through time
- Issue
  - Use of same terms masked semantic disagreements
- Strategy
  - Documented a set of semantic primitives
  - Balanced Contextual, Aspirational, and Behavioral semantics
  - Applied change management to resulting “formalizations”

Semantic Harmonization

- Context: Development of evolving eBusiness standards
- Destabilization vectors
  - Numerous working groups; mix of complementary and divergent interests
  - Each standard seeks to be "the hub"
  - Ambiguity throughout resulting standards
- Goal
  - Harmonization of disparate eBusiness Standards
- Issue
  - General agreement hasn't driven interoperability
- Status: Ongoing
  - Ontolog formed, in part, to drive semantic harmonization
  - Work on Dynamic Semantics an outgrowth of these efforts
  - Further research required to understand issues and derive strategies

Case Studies Summary

	Interpretive Semantics	Contextual Semantics	Aspirational Semantics	Behavioral Semantics
Camping List		X		X
NHIN RFI Response		X	X	
Markup Language	X	X	X	X
Researcher's Notebook	X	X	X	X
Compliance Management		X		X
Advanced Semantics		X	X	X
Semantic Harmonization	X	X		

Semantic Nirvana / Artificial Utopia

- Formalization is optimized for computerized inference
  - First Order Logic typically considered the most expressive representation
- Two-step semantic resolution model
  - Symbol interpretation — Maps symbol to concept
  - Axiomatic component — Used to document, communicate, and potentially infer behavioral implications
- Limitations
  - Limited Contextual and Aspirational Semantics
  - Practical issues limit “expressiveness”
    - Availability of subject matter experts
    - Truth is unbounded but resources are limited
    - Can you read KIF?

MetaKnowledge Formalization

- Doesn't have to be difficult or expensive
- Supports and enables rapid prototyping
  - Scalable from small projects to large knowledge architectures
  - Reporting model starts "right" and improves through time
- Leverages implicit and tacit knowledge within the organization
  - Enables re-contextualization and Knowledge Perpetuation
- Doesn't preclude use of logic-based formalizations
  - Can speed and document emergent consensus
  - Helps ensure alignment of human behavior with axioms

Conclusions

- Formalizing meaning in the face of uncertainty is
  - Difficult, at best
  - Potentially chaotic
- Therefore, an improved ability to identify and understand Dynamic Semantics enables
  - More resiliency to be built in, in the first place
  - Less remediation. Fewer false starts
  - Changes to be more easily anticipated and reacted to
  - Semantic change to be used as a resource for enhancing delivered value
- MK-based analysis and formalization is
  - Less brittle than other approaches
  - Expected to be the foundation for many emerging Ontology Management practices

Next Steps

- Asked to develop workshop series for managers and engineers
- Applying the models to more cases
  - Developing semantically-enriched knowledge representation models
  - Researching economics of ontologies
  - Articulating business cases
- Continue to extend and refine Ontology Management methods
  - Identification of operational ontologies and their boundaries
  - Development of methods to drive organizational alignment
    - Troubleshoot, predict, and avoid semantic breakdowns
  - Drive explicit expression and agreement around core semantic properties
    - Develop quality measures for semantic specifications
    - Articulate complete specifications for logic-based formalization
    - Capture and maintain MK needed to re-contextualize formal ontologies

“If everything seems to be under control, you’re just not going fast enough”

- Mario Andretti

TOMB

Semantic Formalization Alternatives

- Typical two-step semantic resolution model [goes here?]
  - Symbol interpretation — Maps symbol to concept
  - Axiomatic component — Used to document, communicate and potentially infer behavioral implications
- Formalized ontologies are currently considered to be the most complete and expressive form of Semantic Models

KIF Uber Alles

- Note to Conference organizer / publisher
  - This page contains backup graphics for slide 18
  - The B&W graphic might need to be substituted for printouts
  - ! ! ! DO NOT PRINT ! ! !