Context Aware Ontologies

Context aware ontologies for information and system integration

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Introduction

- Cory Casanave
  - Company: Model Driven Solutions, Inc.
  - Object Management Group (OMG) Board of Directors
  - Focus: Actionable architecture - federation, integration, interoperability and automating software solutions
  - Background: Enterprise, information and system modeling more than formal logic
    - Trying to bridge the gap between them and leverage the best aspects of both
  - Working on: “Semantic Modeling for Information Federation“ (SMIF) in OMG
    - Conceptual modeling (reference ontologies) as a foundation for integration and federation
  - Intent: Application of conceptual modeling and actionable architecture to enterprise and government needs
Problem Statement

- Focus: Integration, Interoperability and Federation Leveraging Reference Ontologies*
  - Every major enterprise needs to integrate and federate information and systems, internally and externally
  - Current manual methods are costly, time consuming and error prone. They tend to tie the enterprise system of systems into a complex, anti-agile Gordian knot
  - These many systems are independently conceived, each containing multiple separate definitions of the same or overlapping concepts. These definitions are technology, organization and application specific
  - **Semantic mediation** as been a primary value proposition for Ontologies, but has proved difficult, particularly for systems without a formal underpinning – which is 99.9% of the systems
  - Our proposition is that successful semantic mediation requires context. Ontologies to solve these problems must be context aware.
    - Being *Context aware* requires a level of granularity beyond contextualizing ontologies

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*Reference Ontology*: A set of concepts intended to be referenced by multiple designs, ontologies and schema in support of integration and interoperability among them.

Different from: *Application Ontology*, intended to support reasoning in support of a particular application.
What is context?

- **Context** is anything that impacts the interpretation or truth value of something else.
- There are different kinds of context, **contextual dimensions**. Kinds of context include:
  - **Time** – fundamental to our understanding of the world is that things change. Most relationships and other assertions are only meaningful in the context of a timeframe.
    - Sue’s weight was 50kg on July 1st, 2017.
    - Barack Obama was president of the United States 2/20/2009 until 1/20/2017.
  - **Occurrences** (perdurants) – things that are only true while something is happening.
    - The radar’s range will be reduced while it is raining.
  - **States** - things that are only true when something is in a particular condition.
    - Food services will be reduced when the power is off.
    - The computer is vulnerable when it is connected to the internet.
  - **Authority** - things that are only true within the jurisdiction of some authority (including geopolitical).
    - Radar detectors may not be used within Virginia.
    - “Fairfax” is the name of a City in Virginia.
  - **Interaction** - things that are only true when communicating for a purpose.
    - Mortgage loan applications must include name, address, SSN and current income.
More Contextual Dimensions

- **Social Group** – things that are true for a set of people
  - In French, Germany is called “Allemagne”

- **Location** – things that are true in a particular place
  - The acceleration of gravity is 9.8 m/s² on the surface of the earth

- **Type** – things that are true for kinds of things
  - Mammals have hair

- **System** – things that are true within a specific system
  - Reactor 5, pump A6 is failing

- **Design** – things that are true for a design
  - The victim database contains the victim’s current address and phone number

- **Source (Provenance)** – things that are true within a text, speech act or ontology
  - John’s report said “Reactor 5, pump A6 is failing”

- **Others** – there are many contextual dimensions
  - Things may be in multiple context at the same time

“An Ontology” or theory as a course grain context
A theory of contextualization

- Contextual dimensions are types of context
  - E.g. U.S.A. is a kind of Geopolitical Organization
  - Geopolitical Organization is a kind of context

- Contexts *contextualize* things that have that context
  - `<Thing>` has context `<Context>`, or `<Context>` contextualizes `<Thing>`
  - E.g. U.S.A. *contextualizes* Alaska
  - But, that isn’t specific enough

- Relationships define contextualization for a contextual dimension
  - (`<Geopolitical Entity>` governing `<Region>`) specializes (`<Context>` contextualizes `<Thing>`)  
  - E.g. (U.S.A. *governs* Alaska) implies (U.S.A. *contextualizes* Alaska)
Higher Order Context

- Context, such as time, can apply to other statements
  - <Actual Situation> exists for <Time Interval>
  - (U.S.A. governs Alaska) exists for March 30, 1867 to Unknown
  - (U.S.A. governs Massachusetts) exists for March 4th, 1789 to Unknown

- Rights and Obligations are frequently contextual
  - Citizens of the U.S.A. have right Protessions from Unreasonable Searches and Seizures
    - exists for March 4th, 1789 to Unknown
  - (Workers in the U.S.A. must pay Income Tax) exists for Feb. 3rd, 1913 to Unknown

- Implies
  - Since March 30, 1867 Citizens of Alaska have rights and as of Feb. 3rd, 1913 must pay taxes
Ignoring context is **dangerous**!

- Issues with ignoring context when integrating or federating information or processes
  - Improper integration of information from different timeframes
    - That prescription was for last year!
  - Failure of trust – what information is to be trusted and why
    - We listen to their feed, but it is all lies
  - Violation of compliance, rules are contextual
    - You stored that information in the EU?
  - Consider: “Launch Missile” Vs. Test: “Launch Missile”
    - Sorry Korea!
Humans share a concept of “mass/weight” – all physical things have a mass.

**Mass/weight in data elements**
- May have different labels
- Use different units
- May be required, optional or excluded
- May be past, current, expected, recommended or allowed
- May be represented using various data types (int, real, string, etc)

**But it’s the same mass of the same individual!**
Why would two mappings of the same data on the same day be different? Why would the fields not be the same?

**Bethesda Hospital Records**

**Sue's Physical Report**
- Name: Sue Plankton
- DOB: January 15th, 1968
- SSN: 390-55-8967
- Weight: 134 lbs
- BP: 122/78
- Physical Date: June 3, 2017

**Sue's Home Scale**
- Weight: 131 lbs
- Taken: Dec 3, 2017

**Army Reserve Fitness Report**
- LegalNameString: Sue Plankton
- Birth: January 15th, 1968
- PersonMassKG: Unknown
- PersonBloodPressure: Unknown
- Report Date: Jan 10th, 2018

**Job Application for Fun Fitness Centers**
- PNAME: Sue Plankton
- PBD: January 15th, 1968
- Social: 390-55-8967
- CWeight: 134 lbs
- AppDT: Jan 10th, 2018
Context determines terms & representation (of data) for concepts

Ontological libraries of reference concepts, can serve as a pivot-point between different data representations, or different ontologies. This can power automation of interoperability, integration and federation. However, mappings can be complex and pattern based (the above is a simplification).
Context of time and data determine data interoperability

- Weight measurement is in the context of the physical’s date
- Example data rules (data context)
  - Army Reserve Fitness Report must include Name, DOB, May include Weight and BP if known.
  - Job Application for Fun Fitness Centers must include name, DOB, SSN & Weight
- Example business rules (mapping context)
  - Army Reserve: Recording of a soldier’s weight must be based on a measurement within the last 60 days.
  - Fun Fitness Centers: Recording of weight must be reported from last physical

Ontologically, all living humans have a weight. The concept of weight may be used to ground data in multiple repositories – great!

- Rules for business and data context impact data mappings and therefor interoperability.
- Understanding context and their implications is crucial.
Location Context

- On the surface of the earth, weight and mass are convertible
- The surface of the earth provides a location context for the rule:
  - One Kilogram is equal to approx. 2.20 Pounds

Rule: 1KG = 2.204±0.015 lbs
Holds within 13
**Concept of Context**

**Definition**

A *context* is anything that impacts the interpretation or truth value of something else.

“Propositions” are the interpretations/truth values. “Things” are the something else.

Propositions that hold within a context hold for all things the context contextualizes.
Context as predicates

- A context be false
  - E.g. It is not 2017 or we are not on the surface of the earth.
- If a context is false, propositions do not hold for what the context contextualizes

Context(x) implies propositions that hold within x hold for all things x contextualizes
Candidate Context Model*

- Semantic Modeling for Information Federation (SMIF) conceptual model
History Happened

- Many DBMS (and many ontologies!) only consider the “current state”
  - the past is just as important
- It will always be true that:
  - Barack Obama was president of the United States Jan 20, 2009 - Jan 20, 2013.
  - Donald Trump is/was president of the United States Jan 20, 2013 - Unknown.
  - Sue weighted 134 lbs on June 3rd, 2017
- Historical statements can be just as important as current statements
- Time is a context for when any assertion is made and the timeframe for which it is applicable
- Different data context will have different assumptions about time and history
- Multiplicity and time
  - Consider the impact on multiplicity: A person only has one weight (at a time) but will have many weights that include time context.
  - But, a person only has one brain, for all time
  - Multiplicity constraints should differentiate: at a time Vs. for all time
Situations as Context

Sue’s Stolen key-card vulnerability situation

Sue’s permission situation
Sue has permission to enter building-5

Key-card a5-347 situation
Key-card a5-347 is a credential for Sue’s permission

Key-card stolen situation
Sue’s key-card a5-347 was stolen

Actual situations (& relationships*) are temporal

Timeframe
Jan-1 2005 to Jan 1 2007

Timeframe
Feb-1 2005 to Feb 15th 2005

Timeframe
Feb-1 2005 to Unknown

Timeframe
June-1 2005 to Feb 15th 2005

Situations can be aggregates – assert other situations

Atomic situations are Material or Descriptive relationships*

Situations involve (contextualize) other, related things.

* “Material relations & relators”, see: https://inf.ufes.br/~gguizzardi/AI_IA2016.pdf
Candidate Situation Model (simplified)*

Semantic Modeling for Information Federation (SMIF) conceptual model

- Situations, as context, can assert other situations and involve (contextualize) other entities as properties (e.g. roles, variables)
Type as Context

- Types categorize things of that type
  - Categorizes is a sub-property of contextualizes
- A set of propositions hold for a type
- This set of propositions hold for all things categorized by a type
- “Type” can be modeled as a subtype of “Context”

All living persons have a living brain

Note: Not all rules about living persons are in the context of the type, consider hospital rules.
Candidate Type as Context Model
Perspectives and Context

- A perspective selects which context are true, for that perspective
  - E.g. a perspective can establish timeframe and the set of applicable (asserted) ontologies

- A perspective can order context by precedence, to resolve conflict
  - E.g. a perspective can order ontologies of preferred terms, perhaps French first and English second.

- A perspective is, its self, a context
  - Context hold within a perspective
Perspectives may include time

Sue’s permission situation
Sue has permission to enter building-5

Timeframe
Jan-1 2005 to Jan 1 2006

Sue’s Historical Perspective

Timeframe
Jan-12 2005

True

implies

holds within

Exists for

True

implies

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Sue's permission
Sue has permission to enter building 5

Sue is an authorized actor in the context of the permission to enter building 5

Authorized Actor
Property type

Permitted Action
property type

Enter building 5 is a permitted action in context of Sue’s permission

Relationship Type

Property Binding

Enter building 5 activity
Context, Perspective & “Higher Order” Logics

- Context and perspectives introduce higher order relations.
- As our goal is to capture (model) and formalize how we conceive the world, such higher order relations are a reality we can’t ignore.
- Many reasoning systems are FOL only, how can we reason about context?
  - Option 1 Use a rules approach
  - Option 2 Use a higher order logic
  - Option 3 Pre-compute the context
    1. Asset perspective
    2. Derive “true” context, recursively
    3. Export context-free (FOL) ontology
    4. Infer exported ontology using FOL
- Our focus is reference ontologies, application ontologies have different (and usually more complex) reasoning requirements – a rules approach seems most applicable.

We can build a model and implement this program, can we formalize the semantics?
References

- Relationships and Events: Towards a General Theory of Reification and Truthmaking
  - Nicola Guarino, Giancarlo Guizzardi

- Situation Semantics
  - See references in John Sowa’s presentation

- Semantic Modeling for Information Federation (SMIF)
  - Needs an update, latest complete document: