Information Flow in the Federal Enterprise

Representing the FEA Reference Models in Languages, Logics, Theories, and Models

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Quote

There is the Intentional Interpretant, which is a determination of the mind of the utterer; the Effectional Interpretant, which is a determination of the mind of the interpreter, and the Communicational Interpretant, or say the Cominterpretant, which is a determination of that mind into which the minds of the utterer and the interpreter have to be fused in order that any communication should take place. This mind may be called the commens. It consists of all that is and must be, well understood between utterer and interpreter, at the outset, in order that the sign in question should fulfill its function. This I proceed to explain.[1]

Charles Sanders Peirce, Spring 1906

Fractal Society; Fractal Web

1. The Essential Peirce: Selected Philosophical Writings Volume 2 (1893-1913), in Letters to Lady Welby, Indiana University Press, 1998.

1. Princple: We won't all agree on the same thing some day.

2. Principle: What we build should reflect the behavior of life it supports and life on this planet is a complex adaptive system: Christopher Alexander calls this Living Structure[2].

3. Principle: Behavior in a networked society implies tolerance, deccentralization, test of independent invention, free extension, language mixing, partial understanding.

Purpose

1. Show the principles of Fractal Society; Fractal Web using the notation of Information Flow: The Logic of Distributed Systems[3]

2. Develop an example of a distributed system using the FEA reference models

3. Describe how local logics represent the flow of information in a static representation of the distributed system

4. Explain structure and semantic preserving transformations that create Living Structure in the distributed system

2. The Nature of Order: An Essay on the Art of Building and the Nature of the Universe, Christopher Alexander, Center for Environmental Studies, 2002

3. Information Flow: The Logic of Distributed System, Barwise and Seligman, Cambridge Tracts in Theoretical Computer Science, 1997.

Caveats and Assumptions

1. The information contained herein should not be construed as a representation of administration policy, the opinion of the General Services Administration, the Architecture and Infrastructure Committee, or an endorsement by the GSA OCIO EA team.

2. Applicability of the information referenced in this presentation is currently under critical assessment and any relevance to formal information models as defined under 207d is merely coincidental and the names have been changed to protect the innocent.

3. Federal Enterprise Architecture reference models provide the domain restriction on types and tokens in the distributed system.

4. Description Logics provide the foundation for analyzing the significance of logics in the distributed system.

Classifications

Definition 1. *A classification* $\mathbf{A} = \langle A, \sum_A, \models_A \rangle$ *consists of a set* A *of objects to be classified called tokens of* $\mathbf{A}$*, a set* $\sum_A$ *of objects used to classify the tokens, called the types of* $\mathbf{A}$*, and a binary relation* $\models_A$ *between* A *and* $\sum_A$ *that tells one which tokens are classified as being of which types.*

Figure 1 - Classification diagram

$\sum_A$

$\Big| \models_A$

A

Comment: Classifications formalize context in the technical components of the distributed system.

Constraints

Definition 2. *Let A be a classification and let $\langle \Gamma, \Delta \rangle$ be a sequent of A. A token a o of A satisfies $\langle \Gamma, \Delta \rangle$ provided that if a is of type α for every $\alpha \in \Gamma$ then α is of type α for some $\alpha \in \Delta$. We say that Γ entails Δ in A, written $\Gamma \vdash_A \Delta$, if every token a of A satisfies $\langle \Gamma, \Delta \rangle$, If $\Gamma \vdash_A \Delta$ then the pair $\langle \Gamma, \Delta \rangle$ is called a constraint supported by the classification A.*

Comment: There are five special constraints: entailment, necessity, exhaustive cases, incompatible types, and incoherent types.

Developing the FEA Example ...

Consider the flow of information among three technical components that realize semantic interoperability in a distributed system. Each technical component holds an executable artifact expressing the Federal Enterprise Architecture (FEA) reference models.

The components are a Meta Object Facility (MOF) that holds a Unified Modeling Language (UML) artifact, a triple store that holds a Web Ontology Language (OWL-DL) artifact, and a meta data repository that holds an artifact based on XML Topic Maps (XTM).

Figure 1 Technical Components and Classifications

MOF	Triple Store	Repository
$\sum_M$	$\sum_T$	$\sum_R$
$\Big\vert \; \models_M$	$\Big\vert \; \models_T$	$\Big\vert \; \models_R$

M T R

Theories and Models

Proposition 3. *Given a first-order language L, the truth classification of L is the classification whose types are sentences of L, whose tokens are L-structures, and whose classification relation is defined by* $M \models_{\varphi}$ *iff* φ *is true in M, usually called the theory of M. The token set of a sentence* φ *is the collection of all models of* φ.

Comment: We'll see from structure and semantic preserving transformations, the technical components in our system have different theories and models. Different axiomatic and model theoretic semantics means work!

Theory of Institutions

Definition 4. *An institution consists of an abstract category Sign, the objects of which are called signatures, a functor Sen: Sign* $\rightarrow$ *Set, and a functor Mod:* $Sign^{op} \rightarrow Set$. *Satisfaction is then a parameterized relation* $\models_{\Sigma}$ *between Mod(*Σ*) and Sen(*Σ*), such that the following satisfaction condition holds, for any signature morphism f:* $\Sigma \rightarrow \Sigma^{'}$, *any* $\Sigma^{'}$*-model* $M^{'}$, *and any* Σ*-sentence e:*

$$M^{'} \models_{\Sigma^{'}} f(e) \text{ iff } f(M^{'}) \models_{\Sigma} e$$

where f(e) abbreviates Sen(f)(e) and f($M^{'}$*) abbreviates Mod(f)(*$M^{'}$*); this expresses the invariance of truth under change of notation.*

Comment: Institutions are a trichotomy that adds the ability to change vocabularies. Also in Peirce's semiotics, the sentences are representamen and the signatures are the interpretant.

Infomorphisms

Definition 5. *If* $A = \langle A, \sum_A, \models_A \rangle$ *and* $C = \langle C, \sum_C, \models_C \rangle$ *are classifications then an infomorphism is a pair* $f = (f\hat{}, f\check{})$ *of functions satisfying the analogous biconditional:* $f\check{}(c) \models_A \alpha$ iff $c \models_C f\hat{}(\alpha)$ *for all tokens* c *of* C *and all types* α *of* A*. An infomorphism is represented concisely as* $f\colon A \rightleftarrows C$

Figure 2 - Infomorphism Diagram

$$
\begin{array}{ccc}
 & f\hat{} & \\
\sum_A & \longrightarrow & \sum_C \\
\Big| \models_A & & \Big| \models_C \\
\mathrm{A} & \longleftarrow & \mathrm{C} \\
 & f\check{} &
\end{array}
$$

Comment: Infomorphisms are like interpretations in classical logic where sounds and complete logic in the source and target

Local Logics

Definition 6. *A local logic* $\mathfrak{L} = \langle A, \vdash_{\mathfrak{L}}, N_{\mathfrak{L}} \rangle$ *consists of a classification* A*, a set* $\vdash_{\mathfrak{L}}$ *of sequents (satisfying certain structural rules) involving the types of* A*, called the constraints of* $\mathfrak{L}$ *, and a subset* $N_{\mathfrak{L}} \sqsubseteq A$*, called the normal tokens of* $\mathfrak{L}$*, which satisfy all the constraints of* $\vdash_{\mathfrak{L}}$*. A local logic is sound if every token is normal; it is complete is every sequent that holds of all normal tokens is in the consequence relation* $\vdash_{\mathfrak{L}}$*.*

Comment: Let's use Description Logics as an example ...

Description Logic Expressiveness[4]

Nomen-clature	Meaning	DL-Core SHIN(D)	UML ALHOIN(D)	OWL-DL SHOIN(D)	ER ALN(D)	Topic Maps AL(D)
AL	Atomic Concept Universal Concept Bottom Concept Atomic Negation Intersection Value Restriction Limited Existential Quantification	X	Atomic Concept Value Restriction Limited Existential Quantification (AL-)	X	Atomic Concept Value Restriction Limited Existential Quantification (AL-)	Atomic Concept Value Restriction (AL - -)
C	Full Negation or Complement	X		X		
E	Full existential Quantification	X		X		
H	Role Hierarchies	X	X	X		
I	Inverse Roles	X	X	X		
N	Unqualified Number Restrictions	X	X	X	X	
O	Enumerated Classes			X		
R*	Transitive Roles	X		X		
V	Union Constructor	X		X		
(D)	Datatypes	X	X	X	X	X

4. "A Description Logic for Use as the ODM Core," Lewis Hart and Patrick Emery, EDOC 2004

Developing the FEA Example

with a Structure Preserving Transformation

Assume the M Sentences represent UML Class, Association, and Class; the T Sentences represent OWL Class, Property, Class

$$\begin{array}{ccc} M\ \text{Sentences} & \overset{I}{\longrightarrow} & \text{T Sentences} \\ \Big| \models_M & & \Big| \models_T \\ \text{M Structures} & \underset{I}{\longleftarrow} & \text{T Structures} \end{array}$$

Comment: ouch, this transformation produces OWL Full from ALHOIN(D)

Developing the FEA Example

with a Semi-Semantic Preserving Transformation

Assume the M Sentences represent UML Class, Association, and Class; the T Sentences represent OWL Class and property and the T Structures represent the OWL individuals

$$\begin{array}{ccc} M\ \text{Sentences} & \overset{I}{\longrightarrow} & \text{T Sentences} \\ \Big| \models_M & & \Big| \models_T \\ \text{M Structures} & \underset{I}{\longleftarrow} & \text{T Structures} \end{array}$$

Comment: We generate OWL-DL from ALHOIN(D), but changing the structure requires additional information we didn't have at design time

Sound and Complete

Proposition 7. *Suppose that the token a is of type α. Then a's being of type α carries the information that b is of type β, relative to the channel C, if a and b are connected in C and if the translation $\alpha^{'}$ of α entails the translation $\beta^{'}$ of β in the theory Th(C), where C is the core of C.*

Axiom 8. *f-Intro:* $\frac{\Gamma^{-f} \vdash_A \Delta^{-f}}{\Gamma \vdash_B \Delta}$

Axiom 9. *f-Elim:* $\frac{\Gamma^{f} \vdash_B \Delta^{f}}{\Gamma \vdash_A \Delta}$

Comment: UML and OWL differ in their axiomatic and model theoretic semantics: OCL cannot express the OWL axioms. Consider the design implications of UML asserted and OWL inferred and asserted models.

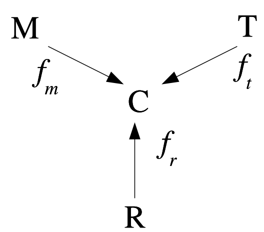
Channel Theory

Definition 10. *An information channel consists of an indexed family* $C = \{ f_i : A_i \rightleftarrows C\}_{i \epsilon I}$ *of infomorphisms with a common codomain* C*, called the core of the channel.*

Comment: What we typically think of as COSMO is the ontology that defines the classification at the core of the channel.

Developing the FEA Example

Figure 2 - Classifications and the Channel in the Distributed System



Comment: In the static representation of the distributed system, the information that can flow through the channel are the normal tokens that satsify all the constraints of the system.

Description Logic

1. Semantic Web Entailment and Description Logic Satisfiability
2. Description Logic and Hybrid Reasoning
3. Description Logic v. First Order Logic

Work Products in OWL-DL

1. FEA Reference Models (FEA-RMO)

   http://www.osera.gov/owl/2004/11/fea/FEA.owl
2. OASIS WS-Reliability - Policy Engine
3. OASIS SAML eAuthentication Profile - Policy Engine
4. Citizen Privacy Act of 1974 - Policy Engine

Information Flow (like) References

1. Information Flow: The Logic of Distributed Systems, Barwise and Seligman

2. Information Flow Framework, Robert E. Kent

3. The Theory of Institutions, Joseph Goguen

4. Computing Fabrics, Erick and Linda VonSchweber