General Motivation: Tightness of Coupling & Semantic Explicitness

**Explicit, Loose**

- Loose
- Same Local Area Network
- Same Wide Area Network
- Same OS
- Same Programming Language
- Linking
- Compiling
- Same Process Space
- Same DBMS
- Federated DBs
- Workflow
- Conceptual Models
- Data Marts
- Data Warehouses
- XML, XML Schema
- Web Services: UDDI, WSDL
- Enterprise Ontologies
- Semantic Mappings
- OWL-S, SAWSDL
- RDF/S, OWL
- Proof, Rules, Modal Policies: RIF, FOL+
- Semantic Brokers
- Web Services: SOAP
- Applets, Java
- N-Tier Architecture
- Same Intranet
- Middleware
- Same Client-Server
- Same Architecture
- Web
- Enterprise
- Community
- Internet
- EA Ontologies
- EA Brokers
- Systems of Systems
- From Synchronous Interaction to Asynchronous Communication
- 1 System: Small Set of Developers
- Looseness of Coupling

**Implicit, TIGHT**

- Tight
- Client-Server
- Same Intranet
- Same Wide Area Network
- Same OS
- Same Programming Language
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**Performance**

$$\text{Performance} = \frac{k}{\text{Integration Flexibility}}$$
Dimensions of Interoperability & Integration

3 Kinds of Integration

Our interest lies here

0% 100%
Interoperability Scale
What is Interoperability?
Dimensions of interoperability

- Two systems are 100% interoperable if:
  - They are very tightly integrated, i.e.:
    - Same memory space
    - Same process space
    - Same control thread
    - If these three hold, then: same operating system
  - Their data structures are the same
  - The semantics (meaning) of their data structures is the same
  - Their knowledge is the same, i.e., the semantics of their object models or ontologies and domain theories (assumptions, metadata, constraints) are the same
  - Their pragmatics are the same, i.e., intent and use
Semantic Interoperability/Integration Definition

- **To interoperate** is to participate in a *common purpose*
  - operation sets the context
  - purpose is the intention, the end to which activity is directed

- **Semantics is fundamentally interpretation**
  - within a particular context
  - from a particular point of view

- **Semantic Interoperability/Integration is fundamentally driven by communication of purpose**
  - participants determined by interpreting capacity to meet operational objectives
  - service obligations and responsibilities explicitly contracted
Towards Semantic Interoperability & Integration

- **Semantic Integration is enabled through:**
  - Establishing base semantic representation via ontologies (class level) and their knowledge bases (instance level)
  - Defining semantic mappings & transformations among ontologies (and treating these mappings as individual theories just like ontologies)
  - Defining algorithms that can determine semantic similarity and employing their output in a semantic mapping facility that uses ontologies

- **The use of ontologies & semantic mapping software can reduce the loss of semantics (meaning) in information exchange among heterogeneous applications**
Our Project: Developing a Clinical Care Ontology for the Veterans Health Administration – Towards a Semantic Electronic Health Record

**Objectives:**

- Explain the advantages and disadvantages of applying Semantic Web technology for enhanced visualization and clinical decision support in EHR systems
- Describe the Clinical Care Ontology, developed as part of this effort, and how it builds on existing clinical terminologies and ontologies
- Appraise the Clinical Care Ontology for its usefulness in EHR visualization using nine clinical use cases spanning diabetes, congestive heart failure, angina, and depression in inpatient and outpatient scenarios
- Describe findings to characterize the value of Semantic Web technology for enhanced EHR visualization and clinical decision support in general
Methodology

- Analyze current ontologies and terminologies
- Develop clinical use cases
- Create or adapt a Clinical Care Ontology
- Evaluate Clinical Care Ontology using clinical use cases
- Evaluate applicability of Semantic Web technology in context of clinical use cases

Goal: support patient-centered, care plan-centered visualization and reasoning
Analyze Current Ontologies

- Ontologies defined in RDF and/or OWL did express clinical concepts needed to support patient care
  - Open Biological Ontologies – OBO
  - General Medical Science (OGMS)
- Upper ontologies contain useful concepts relevant to this work
  - Basic Formal Ontology (BFO)
  - Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE)
- Many ontologies could be linked to the Clinical Care Ontology, effectively serving as instance data
  - Disease Ontology (DO)
  - Systematized Nomenclature for Medicine – Clinical Terms (SNOMED-CT)
  - International Classification of Diseases (ICD)-9 or ICD-10.
- Gaps were identified in the representation of Care Plan, Goal, and Preference
Develop Clinical Use Cases

- **Inpatient Care**
  - Angina
    - Patient presenting to ED with angina, diagnosed with STEMI
    - Telemetry unit care post stent placement through discharge
  - Congestive Heart Failure (CHF)
    - Patient presenting to ED in acute respiratory distress, diagnosed with exacerbation of CHF
    - IMC care through discharge

- **Outpatient Care**
  - Diabetes
    - Newly diagnosed diabetic patient, with follow up care and annual eye exam
  - Depression
    - Management of patient with chronic depression
Create Clinical Care Ontology

- Focus on support to clinical use cases
  - Condition
  - Goal
  - Care Plan
  - Intervention

- Construct quantitative and qualitative value spaces to track patient progress toward goals

- Map value spaces to Goal

- Define Preference(s) on Goal and Intervention

- Establish a sparse scaffolding of upper-level ontology distinctions to ease future mapping to foundational ontologies
Clinical Care Ontology – Care Plan and Goals

Legend:
- Intervention
- State
- Encounter
- Observation

CarePlan

Initial Patient State

Plan CarePlan

Schedule CarePlan

Execute CarePlan

Final Patient State

Condition

Assessment

Diagnose

Incremental Goal

Patient Goal State

Success!
Clinical Care Ontology – Care Plan and Goal
Representing Our Patient

All persons in the scenario are fictitious with characteristics intended to represent the role NOT actual individuals.
Clinical Care Ontology – Quantitative Value Spaces
Clinical Care Ontology – Qualitative Value Spaces

Diagram showing the relationships between Quality, Nominal Quality, Reference Space, Value Space, and Value Set, with properties such as hasReferenceSet, hasReferenceSpace, hasValueSpace, hasNominalValue, hasValue, valueMemberOf, partOf, containsValuesFrom, hasMemberValue, hasReferenceMemberValue, and hasValueSet.
Clinical Care Ontology – Mapping Value Spaces

**Example: Blood Pressure (mmHg) Value Space**

- **ZeroPositiveIntegerValueSpace**
  - **BloodPressureValueRange**
    - **BloodPressureReferenceRange**
      - **DiastolicBloodPressureReferenceRange**
        - **SystolicBloodPressureReferenceRange**
          - **NominalBloodPressureValueSet**

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<tr>
<td>&quot;hypertensive&quot;</td>
<td>140/90 &lt; SPB/DBP</td>
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</tbody>
</table>
Integration of Ontology into EHR Architecture

Forms need to be developed to take advantage of the structure of Care Plans and Goals

Existing services need to be modified to invoke queries to the ontology using new ontology query layer

New services may be necessary to utilize Care Plans and Goals

Database elements must be mapped to appropriate concepts in ontology

New database elements may be necessary to support Care Plans and Goals

Ontology should be mapped to existing vocabulary
Reasoning for Patient-centered Clinical Decision Support

All persons in the scenario are fictitious with characteristics intended to represent the role NOT actual individuals.
Notional Visualization of Patient Progress toward Goals

**Goal**
- Move from obese to overweight
- Achieve target weight of 190 in 4 months
- Current weight: 230
- Target weight: 190

**Interventions**
- Low fat, 12 calorie/day diet
- 1 hour cardio 5 x/week
- Nutritional and Wellness Class

**Observations**
- Weight
- Blood sugar
Next Steps

- Add rule layer to the architecture for richer capability
- Incorporate Clinical Care Ontology into VHA prototype
  - Evaluate ontology further, particularly with regard to value in supporting additional dynamic visualizations
- Continue to refine Clinical Care Ontology
  - Incorporate more detail on mental models
  - Expand on preferences, utility
  - Refine to support VHA prototyping efforts
- Continue to develop a reasoning system
- Share results broadly