Business Value of Semantic SOA

Standards-based interoperability is not enough

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The business model of healthcare is an expert based cottage industry\(^1\)

**Today**
- **Cottage industry model** with expert consultants (physicians)
- No standardized approach to healthcare delivery: consultancy medicine
- No connected healthcare industry
- **Characteristics**: leads to unsustainable cost explosion, not scalable, unpredictable results, inadequate and insufficiently safe patient care

**Future**
- **Value-chain Industry model** with standardized procedures in which physicians act as health engineers applying the laws of evidence-based and causal medicine in a controlled environment (this is an emerging trend, e.g. specialised ophthalmic surgery clinics)
- Connected, integrated industry (like in manufacturing / logistics / retailing)
- **Characteristics**: cost-aware, reliable and reproducible results, high standards of patient care, highly personalized care

**How do we get there?**
- Research and development to obtain more evidence based an causal medicine foundations
- Improvement of business process via IT support [focus of this talk]
- Political, social and economic change

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\(^1\) CM Christensen, The Innovator's Prescription, McGraw Hill, 2009
It is believed by many that the full computerization of healthcare information in a way that enables sharing of data to maximize benefit to the patient and to the healthcare profession can provide huge potential gains and cost savings, e.g. cut crisis-level asthma attacks by 80%, heart attacks and kidney failure by one third$^2$

However, Healthcare information still remains locked away in either paper records or, when computerized, in technological islands:

- Disparate technologies
- Disparate representations (format/syntax)
- Imprecise or varying semantics and levels of semantic richness
- Spread among various organizations: government, payers, providers, hospitals, pharmaceuticals, research institutes etc.

But healthcare IT has lagged behind other industries in many areas for various reasons, some political, some social, some economical – the result is that the software focuses on patient administration and billing using insular and monolithic solutions with storage of only coarse grained, administration relevant data. The systems only support cottage industry medicine

$^2$ G. Halvorson (CEO Kaiser Permanente), Healthcare Reform Now, 2007
To support value chain, industry-style healthcare delivery via IT, interoperability, computable semantics, SOA and standards need to interplay efficiently.
To create a value chain industry-style healthcare delivery process, there are many needs for the effective exchange of healthcare information, e.g.

- Exchange of EHR data to support effective treatment of patients that see multiple providers, e.g. when suffering chronic co-morbidities (diabetes and heart disease)
- Order management (Lab, Rx, Radiology, etc.) and referral processing
- Aggregation: for disease registries, treatment efficacy, signal detection, clinical protocol improvement and real-time feedback into evidence-based medicine
- Regulatory reporting

Levels of Interoperability

- Simple Interoperability (or integration) is the ability to exchange information at a technical and syntactic level
- Semantic Interoperability adds the ability to exchange information with associated meaning
- Computable Semantic Interoperability is the ability to exchange meaningful information that may be directly computed without manual intervention or interpretation
The notion of interoperability and Health Information Exchange (HIE) has been almost a Holy Grail in healthcare in recent years. Billions of dollars have been, and continue to be poured into finding ways of exchanging healthcare information between all participants of the healthcare eco-system.

Right now, very large sums of money are being set aside to address this challenge by Governments throughout the world. In the USA, the Recovery act has provided millions of dollars.

However, if the silos are opened up and healthcare information is exchanged more frequently, how much benefit will truly arise? Are we maximizing the opportunity? Are we raising expectations too high?
eHealth standards are a step in the right direction but often fail to deliver.

**eHealth key SDOs**

<table>
<thead>
<tr>
<th>SDO</th>
<th>Comments</th>
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| IHTSDO | Benefits (today): technical, syntactic interoperability  
Benefits (promised): semantic interoperability |
| HL7 | Issues (social) – do not apply to all standards/SDOs  
- standards plethora with overlapping, competing and inconsistent standards  
- Design by consensus, least common denominator  
- Sometimes too narrow (single solution for everything)  
- Sometimes standards can be used to inhibit innovation |
| OMG | Issues of individual standards  
- Snomed-CT: Strong content, but flawed foundation (not explicitly based on first order logic, misuse of subsumption, no upper ontology, post-coordination design not thought through)  
- HL7v3: Some great domain content knowledge, but fell into trap of over-defining specific infrastructure and language rather than reuse of horizontal standard and causes many problems for implementers. Also refinement model breaks good object oriented engineering practices  
- OMG: Over-focus on MOF – which is a good language for the object technology space but has limitations, especially for the AI area; no focus on declarative software specification language (though imperative action language has its important merits)  
- W3C: The semantic web has popularized semantic technology, but, in practice, the technology is still too focused on syntax (linked data, RDF) rather than actual semantics (OWL, DL). |

**Conclusion:** A compelling industry solution in addition to standards is needed – but this requires huge investments
Another key issue is that where healthcare information is actually captured in an electronic form, it is often textual or at best in a very basic syntactic format or the same information is represented in many different ways.

The work to extract information and transform in a meaningful way to make it useful for disease management, drug efficacy analysis, signal detection and real-time clinical decision making is huge.

The key goal is to achieve deterministic “computable semantics.”

Our contention is that while the huge investment into interoperability is worthwhile, it is simply not enough to exchange information at the level of semantic awareness that is prevalent in today’s systems.

And this severely limits the value of interoperability, often down to just technical and syntactic levels.
Computable Semantics and SOA

- The use of well architected, flexible, semantically robust systems based on well defined information models, data types and rigorously defined ontologies / terminologies, coupled with rigorously defined behavior and reasoning / inferencing can overcome many of the challenges via “semantic disambiguation”

- Information must be captured and managed in a truly semantically rich and robust fashion in the first place. This calls for a change in the way most healthcare applications are designed and constructed

- We believe that (at least) the following elements are needed:
  - Well defined information models (preferably, but not necessarily common/shared). Examples being HL7 RIM (beware) or OpenEHR Archetypes
  - Robust Data Types or compositional data structures, such as OpenEHR Datatypes or HL7/ISO 21090
  - Ontology-based terminologies based on sound mathematical theory
  - SOA Service framework to manage the components to provide appropriate modular functionality and a pathway to migration, with proper Process / Function separation
  - A configurable, flexible environment for managing models, terminologies and binding between them, as well as mappings and transformations
Computable Semantics Components

Computable Semantics

Semantic Enablers
- Semantic static domain information models

Knowledge representation (ontologies, terminologies)

Business process representation (rules, dynamic/behavioural models)

System architecture (SOA)

Semantic system behaviour models / Services

System realisation
WS-services, ESB/EJB3, Java, Lisp, .NET, C# etc.

Engineering Enablers
**Semantic Data Representation**

**Binding implicit meaning to explicit representations**

<table>
<thead>
<tr>
<th>Syntactic: flat table with ambiguous data meaning implicit in rules outside the system</th>
<th>Semantic: meaning of data unambiguously represented within healthcare systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>AG_Test ... AG_Result ... AG_Column_N</td>
<td>Information model (OpenEHR Archetypes or HL7 RIM and ISO data types)</td>
</tr>
<tr>
<td><strong>Record 1</strong></td>
<td>Controlled Vocabularies Snomed CT / LOINC / MedDRA</td>
</tr>
<tr>
<td>...</td>
<td>Business Rules (here: ontologic representation)</td>
</tr>
<tr>
<td><strong>Case X</strong></td>
<td>Service framework and specifications</td>
</tr>
<tr>
<td>Serum Glucose</td>
<td>Company &amp; Vendor E2B Mapping</td>
</tr>
<tr>
<td>90</td>
<td></td>
</tr>
<tr>
<td><strong>Record N</strong></td>
<td></td>
</tr>
</tbody>
</table>

Data stored with semantics implicit in the **data entry rules** and the **database table structure**. Any processing of the value requires human modelling e.g. to create an output message or to generate meaningful statistics or to enrich the data.
Services, models and terminologies are used to support business processes via workflow and rules.
SOA - eHealth Services

- Application 1
- Application 2
- Application 3
- Application 4

**Transactional Services**
- Business capability services
- Data import and migration
- Identity Resolution
- Information Management

**Semantic Services**
- Terminology/ontology
- Metadata access
- Domain model mgmt
- Business rules management and execution
- Reasoning and knowledge
- Concept resolution

**Analytical Services**
- ETL
- Data warehouse access
- Statistical Modelling
- Standard Reports
- Custom analysis
Putting It All Together

Regulator

Pharmaceutical

Payer

Hospital

Cloud Connectivity and Semantic xform

Analytics Repository

Semantic Infrastructure

semantic transform

semantic transform

semantic transform

semantic infrastructure

semantic infrastructure

semantic infrastructure
Today’s systems focus on patient administration support. Semantic systems can support the treatment of a patient by decision support and can improve medical knowledge by allowing much deeper epidemiologic studies. All this reduces the costs of patient care by increasing efficiency and efficacy. Furthermore, well architected systems can adapt to change and are easier to integrate with each-other.

SOA systems realizing semantic interoperability can support the transition from cottage-industry to value chain industry-style healthcare delivery.
ii4sm – the International Institute for the Safety of Medicines – is designing and building a platform for Computable Semantics and Interoperability (CS&I) with the following features to address these challenges:

- Dynamic information modeling environment to support expression of rich semantic models and run time instantiation and management of graphs of objects with automated validation and transformations.
- Support for different information models and rich data types
- Flexible configuration mechanisms for managing model and process variations and localizations
- Description logic based Ontology Management Service to manage terminologies and other ontologies, which permit full reasoning and inferencing
- Rules based binding of Information models and terminology models / value sets
- Approaches and tools for semantic enrichment of legacy data (where feasible)