Ontologies and semantic Business Process Management

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Outline

- About Me & DERI
- Business Process Management
- Problems in traditional BPM
- Semantic Business Process Management Business
About Me & DERI

- 5th-year PhD student
- DERI
  - Currently three locations
    - DERI Galway, Ireland
    - DERI Stanford, USA
    - DERI Korea, Seoul
  - ~ 100 members
- Research interests
  - Semantic Web
  - Business Process Management
  - Service-oriented architectures
- Achievements
  - Co-authored W3C Member Submission WSMX
  - Coined Semantic Service Oriented Architecture
Business Process Management
The Critical Business / IT Divide

Business Experts’ Perspective

Querying the Process Space
- reduce costs
- increase product quality
- improve throughput times
- less training
- less support required
- increase forecast accuracy

Bridging Business-IT gap
- reduce implementation costs
- implementing the real requirements
- faster implementation
- less support requests
- align implementation

IT Implementer’s Perspective

Models

How do I execute this process in the IT system?
Different Models exist with different:
- Applications
- Modeling methods
- Scope

Possible abstraction layers
- Requirements definition
- Design specification
- Implementation specification
- Execution and run-time models
Enterprise Models:

“... a computational representation of the structure, activities, processes, information, resources, people, behavior, goals, and constraints of a business, government, or other enterprises.”

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<td></td>
<td>e.g. UML Class Diagram, ER Model</td>
<td>e.g. Function Modeling</td>
<td>e.g. Business Logistics System</td>
<td>e.g. Workflow Model</td>
<td>e.g. Master Schedule</td>
<td>e.g. Business Plan, Strategic Maps</td>
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Enterprise Models

- **Generic models for enterprise architectures:**
  - Zachman Framework (highly structured, spanning all aspects)
  - CIMOSA (European counterpart)
  - ARIS (scientifically designed model now used by IDS Scheer)
  - TOGAF (ANSI/IEEE standard architecture specification)
  - ...

- **... models with focus on process design & execution:**
  - BPMN (comprehensive graphical notation)
  - EPC (graphical notation)
  - UML Activity diagrams (popular standard model maintained by OMG)
  - XPDL (interchange language)
  - BPEL (execution language)
  - ...
“Composition of service functionality to achieve a certain goal in the scope of a collaboration.”

- Business Process Models
  ... can span multiple enterprises
    - Private Process
    - Public Process
  ... separate coordination (choreography) and control (orchestration)
Example

BPM ancestors - History

- **70’s / 80’s: Information systems with hard-coded workflows**
  - Office automation systems
- **late 80’s / 90’s: Generic workflow systems**
  - Generic, but proprietary meta model
- **90’s: Generic “standardised” workflow systems**
  - Explicit process models
  - Interface architecture to control applications
- **Today:**
- **Business Process Management systems**
  - Web Service paradigm
  - Orchestration and Choreography control
- **Process Aware Systems**
  - Process Management on top of existing systems (ERP, SCM, CRM...)

Digital Enterprise Research Institute www.deri.ie
BPM modelling layers

1. **Languages/Models**
   - defining generic concepts to describe model types (e.g. UML, BPEL).

2. **Instance of a Process Meta-Model.**
   - Defines a model to describe a domain (e.g. Purchase Order Process).

3. **Instance of a Process Model.**
   - Run-time behaviour of a process (e.g. `<PO_started_101107>`).
Process Meta-Models


  - is a logic formalism
  - represents changing scenarios as a set of second-order logic formulae
  - basic elements of the calculus are:
    - actions that can be performed in the world
    - fluents that describe the state of the world
    - situations (A situation represents a history of action occurrences)
Process Meta-Models

Process Algebras

- 1978: CSP. Communicating Sequential Processes (CSP) [Hoare, 1978]. Subsequently developed into a fully-fledged process calculus during the early 1980’s.

Features that all process algebras have in common:

- message-passing
- Describing processes and systems using a small collection of primitives, and operators for combining those primitives
- Defining algebraic laws for those process operators $\rightarrow$ equational reasoning
1962 – now: Finite State Machines (FSM) [Hopcroft et al., 2001]

- originates in finite automata. A Finite Automaton is a more formal notion than a FSM

- Notion of FSMs was introduced to be more usable for computer science. A FSM is defined by the following:
  - a finite non empty set of states
  - an initial state
  - a finite non empty set of distinct input events or their categories
  - state transitions
  - actions
Process Meta-Languages

- BPELJ
- BPEL4People
- BPEL-SPE
- ?...

- BPMN
  (OMG)

- WS-CDL
  (W3C)

- BPXL
  (bpml.org)

- BPEL
  (IBM, Microsoft, BEA → OASIS)

- GPEL

- YAWL
  (Research)

- GSFL

- WSFL
  (IBM)

- XLANG
  (Microsoft)

- XPDL
  (WfMC)

- BPML
  (bpml.org)

- WSCI
  (SUN, SAP, Oracle)

- BPSS
  (OASIS ebXML)

- FDML
  (IBM)

- FDL
  (IBM)
- Workflows have multiple perspectives, depending on author the number of core perspectives differ:
  - Control Flow perspective
  - Informational perspective
  - Organization perspective
  - Operational perspective

- Other dimensions exist
  - No agreement on standard model
  - Multiple notations and languages
WfMC Reference Model

1. Process Definition Tools
   - Interface 1

2. Workflow API and Interchange formats
   - Interface 2
   - Interface 3

3. Workflow Enactment Service
   - Interface 4

4. Invoked Applications

5. Administration & Monitoring Tools
   - Interface 5

Other Workflow Enactment Service(s)

Workflow Engine(s)

Workflow Engine(s)

Client Applications
WfMC Reference Model

- **Build-time**
  - Defining
  - Modelling
WfMC Reference Model

- **Run-time control**
  - Manage instances
  - Sequence activities

- **Run-time interactions**
  - With humans
  - With applications
Run-time monitoring

- Display status of running or completed workflow instances
- View task lists for users or roles
- Display system workload
BPM Market Space

Dimensions in Web Service Flows

- **BPM only incorporates three dimensions**
  - Control Flow
  - Informational
  - Operational

- **Web services are the only operational entity**

- **Drawback: no organisational dimension**
  - But efforts exist: BPEL4People
BPEL

- BPM language/model
- Language to specify behaviour of business processes
- Executable and Abstract processes
  - Executable processes
    - Executed within a compliant environment (portability)
  - Abstract processes
    - Specify constraints of message exchange
    - Provide “views” on internal processes
- Combination of graph-based language (IBM WSFL) and calculus-based language (Microsoft XLANG)
Problems in traditional BPM
Problems in traditional BPM

- **Business Process Management (BPM)**
  - management, implementation, and monitoring of processes in enterprises
  - many BPM technologies exist
  - SOA as new principle

- **BUT: several insufficiencies**
  - Business – IT – Divide (different worlds)
  - incompatible modelling languages
  - Business Process Modeling & Execution
    - syntactic process specification languages
    - hard-wired Web Service Execution (inflexible)

- **Aim of Semantic BPM:**
  - “ontologise” the BPM Life Cycle
  - enhance BPEL with Semantic Web Services
Problem Setting

Here is my business process! I think this solves my business problem nicely...

A¹ → A² → A³ → A⁴

Nice try, but it won’t run... You need to specify the services that perform each step!
Problem Setting

I don’t understand about these technical details!
This is my view on the process...

A¹ → A² → A³ → A⁴

o.k. no problem, I will help you...

Making Semantic Web real.
Semantic Matching of Activities and Services

Semantic Web Services
Matching Model Representations & Semantics

Here is my business process!

Business Representation

A ➔ B ➔ C

M

IT Representation

α ➔ β ➔ γ ➔ δ ➔ χ

Wow! This is perfect – nothing left to do for me!
Aim of Semantic BPM

Business Experts’ Perspective: Processes

Machine-Accessible Representation of Business Experts’ Requirements

Mechanized Mediation based on Machine Reasoning

Machine-Accessible Representation of Processes, Process Fragments, and IT Infrastructure as Semantic Web Services

IT Implementation Perspective
Semantic Business Process Management
Semantics for the WWW

Dynamic

Web Services
UDDI, WSDL, SOAP

Semantic Web Services

Static

WWW
URI, HTML, HTTP

Semantic Web
RDF, RDF(S), OWL
The Semantic Web

- next generation of the Internet (augmentation of the WWW)
- information has machine-processable and machine-understandable semantics
- ontologies as base technology for semantic interoperability
Definition:

- Unambiguous terminology definitions
- Conceptual model of a domain (ontological theory)
- Machine-readability with computational semantics
- Formally explicit specification of a shared conceptualization
- Commonly accepted understanding
## Types of Ontologies

- Ad-Hoc Hierarchies (e.g. Yahoo)
- XML DTD Schema
- XML Schema
- Formal Taxonomies
- Frames
- Value Restrictions
- General Logical Constraints
- First-Order Logic (PSL)
Formal Ontology

- **Concept**
  - conceptual entity of domain

- **Property**
  - attribute describing a concept

- **Relation**
  - relationship between concepts or properties

- **Axiom**
  - coherency description between Concepts / Properties / Relations via logical expressions

Diagram:

- Person
  - email
  - research field
- Professor
  - holds
  - lecture nr.
  - research field
- Lecture
  - topic
  - attends
- Student
  - ID
  - name

Axiom:

\[
\text{holds}(\text{Professor}, \text{Lecture}) \implies \text{Lecture.topic} = \text{Professor.researchField}
\]
Ontology Languages

- Requirements
  - expressivity
  - reasoning support
  - web compliance

W3C Semantic Web Language Layer Cake
revised version, Tim-Berners-Lee 2005
Web Services & SOA

- **Web Service** = program accessible over the Web

- **Service-Oriented Architecture (SOA):**
  - use Web services as basic building blocks
  - dynamically find & invoke those Web services
  - that allow to solve a particular request

- **Web Service Technologies:**
  - WSDL  Web Service Description Language
  - SOAP   XML data exchange protocol for the Web
  - UDDI   registry for Web Services
The Web Service Usage Process

- **Repository**
  - find usable Web Service

- **WSDL**
  - describes

- **Consumer**
  - SOAP
  - WS usage via message exchange
Deficiencies of WS Technology

- current technologies allow usage of Web Services but:
  - only syntactical information descriptions
  - syntactic support for discovery, composition and execution
  - \( \Rightarrow \) Web Service usability, usage, and integration needs to be inspected manually
  - no semantically marked up content / services
  - no support for the Semantic Web

\( \Rightarrow \) initial Web Service Technology Stack failed to realize the SOA Vision
Semantic Web Services

- automate Web Service technologies by
  1. rich, formal annotation of Web Services
  2. automated detection and execution of Web services

- integration with the Semantic Web
  - ontologies as data model
  - Web Services as integral part of the WWW

- inference-based techniques for automated discovery, composition, mediation, execution of Web Services
a) Web Service Description Structure

- Interface
  - Web Service Implementation
    - (not of interest in Web Service Description)
  - XML

b) Semantic Web Service Description Structure

- Interface
  - Non-functional
  - Functionality
  - Web Service Implementation
    - (not of interest in Web Service Description)
- Aggregation
  - Ontology
    - Ontology
    - Ontology

Semantic Web Services
Objectives that a client may have when consulting a Web Service

Provide the formally specified terminology of the information used by all other components.

Semantic description of Web Services:
- **Capability** (*functional*)
- **Interfaces** (*usage*)

Connectors between components with mediation facilities for handling heterogeneities.
WSMO Web Service Description

- complete item description
- quality aspects
- Web Service Management

Non-functional Properties

DC + QoS + Version + financial

Capability

functional description

- Advertising of Web Service
- Support for WS Discovery

Web Service Implementation

(not of interest in Web Service Description)

realization of functionality by aggregation
- functional decomposition
- WS composition

Interface

client-service interaction interface for consuming WS
- external visible behavior
- communication structure
- ‘grounding’

Orchestration

Making Semantic Web real.
- **Concept example**
  
  ```xml
  concept phoneNumber
  nonFunctionalProperties
dc#description hasValue "concept of a phone number"
  endNonFunctionalProperties
  countryCode ofType _string
  areaCode ofType _string
  number ofType _string
  ```

- **Relation example**
  
  ```xml
  relation hasRoute(ofType routeDescription, ofType route)
  nonFunctionalProperties
dc#description hasValue "Relation that holds between a route description and a route"
  endNonFunctionalProperties
  ```

- **Instance example**
  
  ```xml
  instance myPhoneNumber memberOf phoneNumber
countryCode hasValue "43"
  areaCode hasValue "664"
  number hasValue "49322607"
  ```

- **Sub-concept example**
  
  ```xml
  concept mobilePhoneNumber subConceptOf phoneNumber
  nonFunctionalProperties
dc#description hasValue "concept of a mobile phone number"
  endNonFunctionalProperties
  mobileProvider ofType Provider
  ```

- **Axiom example**
  
  ```xml
  axiom ValidInformationQuality
definedBy
  forall {?x} (
    ?x memberOf informationQualityType
    implies
    ?x[value hasValue "low"] or
    ?x[value hasValue "high"]).
  ```
Automated Web Service Usage

Goal

buy train ticket in Finland
- origin: o, destination: d
- date-time: dt

instantiates

goal instance with inputs:
o = Tampere, d = Turku
dt = 20071219-1030

defines

Client

Mediator

client interface

VR Train Ticketing

design time

runtime

executes
From Syntactic to Semantic BPEL

a) BPEL Process

b) Semantic BPEL Process

WS
WS
WS
XML

WS
WS
WS

WSMO Goal
Goal

Semantic Service Oriented Architecture

dynamic detection at runtime

Ontology
Mediator
Concluding Remarks

- After 25 years still no standard Process Model established yet → trend towards BPEL for execution standard
- Ontologies in BPM give one:
  - Higher Flexibility for Web service usage
  - Formal Semantics of Data (messages exchanged)
  - Automated Handling of potential heterogeneities
  - better understandable for humans (different abstraction layers)

- Important for you – Take Home Message:
  - Understand the terminology (Process Model, WfM, BPM, Meta Model, Process Model, Instance, Abstraction levels, etc.)
  - Know BPEL and understand its meta model
  - Try one of the Open Source BPEL Engines available on http://sourceforge.net/
Questions?

Interested in doing research on BPM, SOA and ontological frameworks? Please, drop an email to me armin.haller@deri.org or hr@deri.org to get information how to apply at our institute.

- Openings relevant for you:
  - intern for up to 6 months
  - Master thesis as visiting researcher
  - Master or Ph.D. student
References


References (cont’d)


