A Standard-based approach to interoperability: the Process Specification Language (PSL)

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Outline

► Part I: The need for interoperability.
► Part II: A standard-based approach.
► Part III: What is the Process Specification Language (PSL)?
► Part IV: PSL in action.
Part I: The need for interoperability
Interoperability: definitions

- The ability to share technical and business information throughout an extended enterprise (such as a supply chain).
- The ability of software on multiple machines from multiple vendors to communicate.
- The ability to exchange data, processes and information
Challenges to communication

Enterprise A

vehicle

material

resource

workpiece

Enterprise B
Challenges to inter-operability

Semantic challenge 1: synonymy

Transportation

Vehicle

Scheduler B

Truck

Process Planner A

Mobile Resource

Process Planner C
The case for manufacturing processes

Exchange of Processes

The Design Life Cycle

Modeling  Planning  Scheduling  Simulation

O  I  O  I  O  I

Application A

Resource (rA)  Machine_tool

Application B

Resource (rB)  Material
Process Specification Language

► A neutral, standard description of manufacturing processes expressed in KIF
► A core ontology and extensions for each process domain
► Translation mechanisms between individual applications and PSL
► Two pilot implementations completed

http://www.mel.nist.gov/psl
Some axioms in PSL

► Core concepts
  ▪ activity, object, timepoint
  ▪ activity occurrence

► Concepts for object
  ▪ resource roles, paths, sets, usage, etc…
  ▪ states

► Relations
  ▪ before, begin_of, participates_in

http://www.mel.nist.gov/psl/psl-ontology/
Process Exchange using PSL

- The ontology for each application is expressed using PSL concepts
- A direct mapping can occur
- OR the application’s term is more restrictive => constraints on its use
- OR PSL is extended to accommodate a new concept
The need for interoperability

► The ability to share technical and business information throughout an extended enterprise (supply chain) implies:

- The ability of software on multiple machines from multiple vendors to communicate, in particular,
- The ability to exchange data, processes and information

Example: the design life cycle

- Process Modeling
- Design Modeling
- Scheduling
- Simulation

O I O I O

► The cost of a lack of interoperability:

- The US automotive sector expended $1 billion per year in 1999 to resolve interoperability issues
- 50% of this cost attributed to data file exchange.
- Study commissioned by the National Institute of Standards and Technology
Challenges to interoperability

- Creation and support of virtual enterprises hindered by the lack of a common understanding of their business processes.

- A common language for processes enables the integration of the business practices of partners within the virtual enterprise.
When should we use the Process Specification Language?

Scenario 1
- n planners,
- m schedulers,
- m * n translators

Scenario 2: use of PSL
- n planners,
- m schedulers,
- m + n translators
Who is the target audience for PSL?

► **End users**
  - Engineers, staff, anyone who needs to exchange process information among applications within their company
  - Collaborators from partnering companies
  - Suppliers and customers in vertical integration

► **Prescribers**
  - Software developers and vendors who produce the design tools, such as CAD, project planning softwares, etc…need to incorporate PSL translators into their tools
  - Make design tools PSL compliant.
The Architecture of PSL

► A computer-readable language
  - specifies entities such as concepts, terminology, and relationships for manufacturing processes
  - includes axioms constraining the use of entities and relationships between them

► Structure of the language
  - A core and outer core
  - Theories
  - Definitional extensions
What are ontologies?

► The basic terms and relations comprising the vocabulary of a topic area
► A set of definitions for these terms
► The rules for combining terms and relations
Some definitions

Definition: Definitions [in an ontology] associate the names of entities of discourse (i.e. classes, relations, functions or other objects) with human-readable text describing what the names mean, and formal axioms the constrain the interpretation and well-formed use of these names. (Huhns and Singh, 1997, “Ontologies for agents”)

Definition: A theory defines its ontology by defining entities which exist in its reality. These entities cannot be reduced or eliminated by analysis from the theory.
Standardization: ISO 18629, SC4, TC 184

► Part 10 Series: Core Theories
  - Part 11: PSL-Core
  - Part 12: Outer Core
  - Part 13: Duration and Ordering Theories
  - Part 14: Resource Theories
  - Part 15: Actor and Agent Theories

► Part 2X: External Mappings
  - EXPRESS, XML, UML

► Part 40 Series: Definitional Extensions of PSL
  - Part 41: Activity Extensions
  - Part 42: Temporal and State Extensions
  - Part 43: Activity Ordering and Duration Extensions
  - Part 44: Resource Roles
  - Part 45: Resource Sets
  - Part 46: Processor Activity Extensions
PSL Core, Outer-core, and Dependencies

**PSL Core**

- Activity
- Activity_occurrence
- Timepoint
- Object
- Before
- Occurrence_of
- Participates_in
- Beginof
- Endof
- Inf+, Inf -

**Diagram:**

- PSL Outer Core
  - Activity Occurrences
    - Complex Activities
    - Atomic Activities
    - Occurrence Trees
    - Subactivity
    - Discrete State

- PSL Core
Using PSL for translating between two applications

- **Syntactic translation for two applications**
  - Application native syntax is parsed to PSL syntax
  - Application concepts are expressed in KIF

- **Semantic translation**
  - KIF definitions are written for application concepts using PSL reserved terminology and relations
  - A 20-question wizard assists in the process

- Application A concepts are translated to PSL
- Application B concepts are translated to PSL and a reverse index is created.
Process Exchange using PSL

Application A
own syntax & terminology

Syntax into KIF

Application A ontology

Application A expressed using PSL concepts

Parsing of relevant PSL concepts for Application B

Application B
own syntax & terminology

Syntax into KIF

Application B ontology

Application B expressed using PSL concepts
Expressing Application A concepts using PSL

1. (forall (?r)
   (=> (inject_mold)
       (rA ?r)))

2. (forall (?r ?a)
   (<=> (rA ?r)
       (exists (?a)
           (reusable ?r ?a))))

3. Unconditional mapping to PSL concepts
   (forall (?r)
       (<=> (rA ?r)
           (and resource ?r)
           (reusable ?r)))

Syntax into KIF

Application A own syntax & terminology

Application A ontology

Application A expressed using PSL concepts
Expressing Application B concepts using PSL

One additional step: inverting the table

(\text{Application B} \Rightarrow \text{PSL})

(\text{PSL} \Rightarrow \text{Application B})
Twenty Question Wizard

Classes of Atomic Activities

Constraints on Atomic Activity Occurrences
The first set of questions characterizes the conditions under which atomic activities can possibly occur; these are often referred to as the preconditions for the activity.

1. Unconstrained Atomic Activity Occurrences
   - Are there any constraints on the occurrence of the atomic activity?
     - There are no constraints on the occurrence of the atomic activity, the activity is always possible.
     - There are constraints on the occurrence of the atomic activity, but the activity is always possible under certain conditions.
     - There are constraints on the occurrence of the atomic activity, there are circumstances under which the activity is not possible and cannot occur, no matter what other activity occurrence preceded it.

2. Constraints on Atomic Activity Occurrences based on State
   - Are the constraints on the occurrence of the atomic activity based only on the state prior to the activity occurrence?
   - Any occurrence of the activity depends only on events that hold prior to the activity occurrence.
Interoperability in Construction

► Scenario: The design and construction of an office building
► Includes an exchange of data regarding fitting a metal door to a wall frame
► Use of an AutoCAD software
► Use of Microsoft Project for the planning phase

Credit: Genet Tesfagaber, Loughborough University
AutoCAD Process “door frame assembly” using PSL

(forall (?a)
 (⇔ (doorframe_assembly)
  (and (activity ?a)
   (constrained ?a)
   (markov_precond ?a)
   (rigid_time ?a)
   (rigid_mixed ?a)
   (context_free ?a)
   (markov_effects ?a)
   (non-temporal ?a)
   (rigid_mixed_effects ?a)
 )))

the activity occurrence is not possible under certain circumstances

the occurrence depends on the state of other activities

the occurrence does not depend on the duration of other activities
MS Project Task “door frame assembly” using PSL

(forall (?a)
  (↔ (doorframe_assembly)
    (and (activity ?a)
      (constrained ?a)
      (markov_precond ?a)
      (time_precond ?a)
      (mixed_precond ?a)
      (context_free ?a)
      (rigid_state_effects ?a)
      (rigid_time_effects ?a)
      (rigid_mixed_effects ?a)
    )))

the activity occurrence is not possible under certain circumstances

the occurrence depends on the state of other activities

the initiation depends on the duration of other activities
Future challenges and issues

- Logically defined specification of processes
  - Mathematical operators and logical format
  - Quality/success is measurable (consistency checking)
- Automation of translation has been prototyped
  - Implemented translation of processes between an IDEF3 planner and a C++ scheduler
- May serve as an ontology for an agent-based system

- Implementation of translators in the products of software vendors
  - Socio-cultural issues prevail
- Need to reach critical mass for design and associated software applications
- Currently no Web implementation or use of state-of-the-art Web protocol
- Diffusing and accessing the standard
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