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Semantic Technologies For Business Process Management

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Outline

- (Semantic) Business Process Management
  - Introducing Business Process Management
  - Business Process Interoperability
  - Semantic Approaches for Enterprise Modeling
- Reasoning on Semantically Enriched Business Processes
  - BPAL Framework
  - Querying BPAL Business Process Knowledge Bases
- Students' Project Proposals

(Semantic) Business Process Management

Business Processes and Workflows

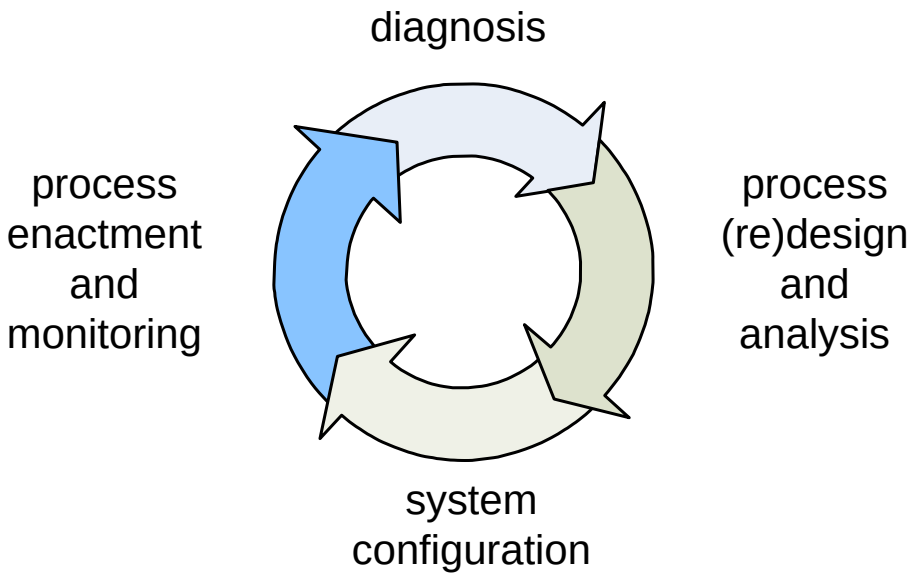
- A Business Process (BP) consists of a set of activities that are performed in coordination in an organizational and technical environments. These activities jointly realize a business goal. Each BP is enacted by a single organization, but it may interact with BPs performed by other organizations [1].

- A Workflow system automates a BP, in whole or in part, during which documents, information, or tasks are passed from one participant to another for action.

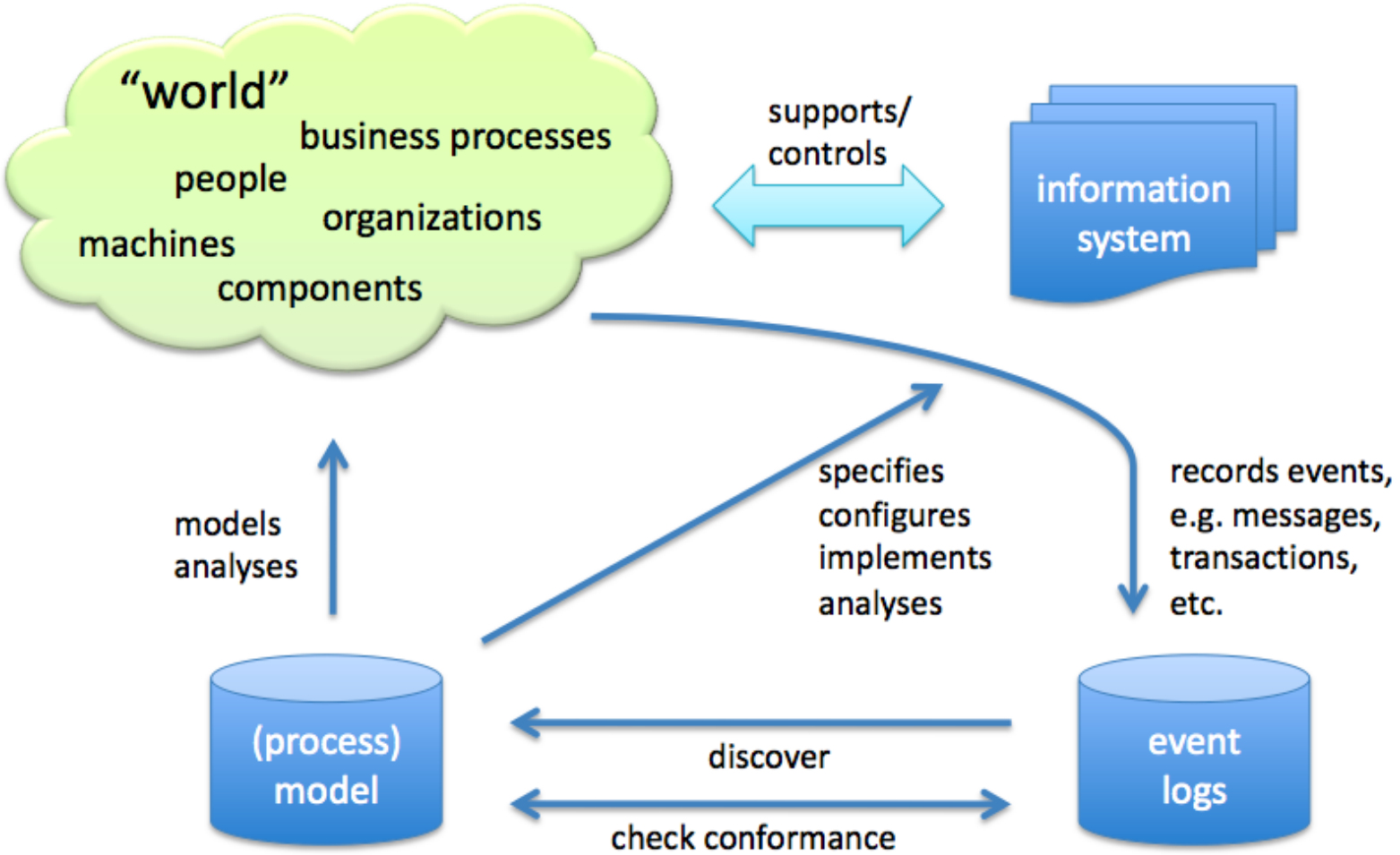
- A workflow typically involves:
  - Activities
  - Decision Points
  - Routes (e.g., sequential, parallel)
  - Resources
  - Roles

Business Process Management (BPM)

- BP Management is a collection of methods and techniques to assist business practitioners and employees in the management of business processes along their entire life cycle [2].
  - BPM views processes as central in an organization
  - Potential for substantial cost & time savings (e.g. business process improvement)
  - Managerial and technical ramifications



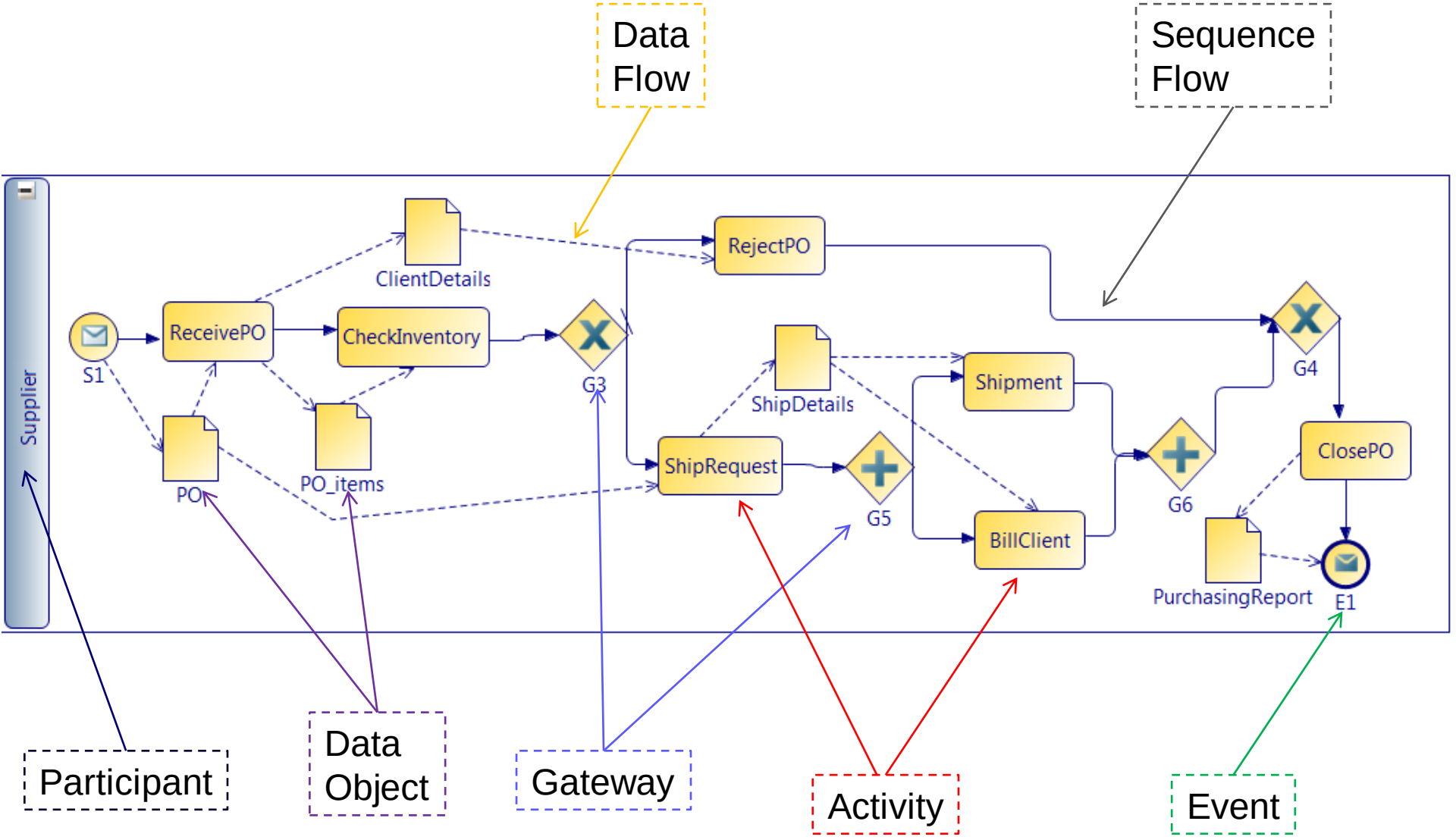
On the role of models (from [2])



BP Modelling Languages

- The Business Process Modelling Notation (BPMN)
  - Graphical notation for process modelling
  - OMG standard (current version 2.0)
  - Not executable, designed for conceptual modelling (semantics loosely defined)
  - XPDL 2.0 as XML serialization
- Business Process Execution Language (BPEL)
  - Derived from IBM's WSFL and Microsoft's XLANG
  - Define executable Web service orchestrations (XML, SOAP, WSDL)
- Yet Another Workflow Language (YAWL)
  - Formal Semantics (Petri-nets)
  - Comprehensive support for the workflow patterns

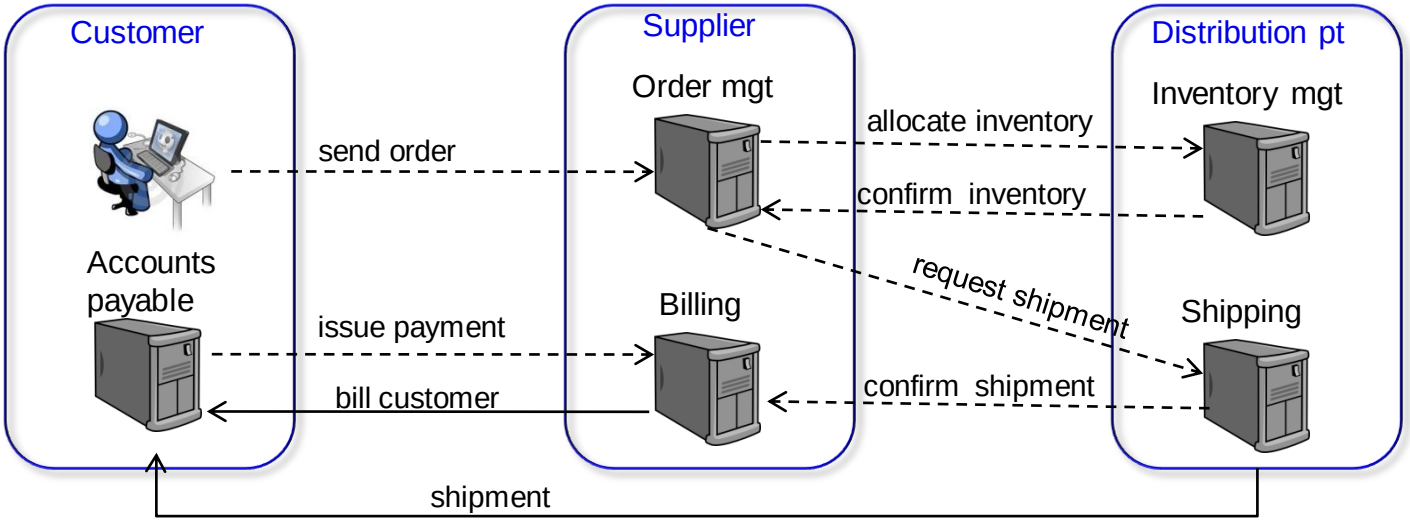
BPMN Overview



Cross-Enterprise Business Processes

- Strong acceleration towards new forms of cooperation among enterprises
  - A networked enterprise integrates the resources of the participating organizations allowing them to pursue shared objectives in a tightly coordinated fashion, operating as a unique (virtual) organization.

- BP Integration deals with the definition of a global commonly accepted BP that specifies execution logic and the information exchange between multiple interconnected enterprises to form a *single logical system.*



The Role of SOA

- Service Oriented Architecture is a design philosophy where a system is designed to provide services to either end-user applications or other services distributed in a network, via published and discoverable interfaces.

- The implementation of SOA through Web Services, allow packaged functionalities to be offered as a suite of "interoperable" services, with interfaces defined independently from the *underlying technologies.*

- *Business Processes defined as Service orchestrations*
  - built from a logically interrelated collection of services, possibly implemented and deployed as web services;
  - composite services can be defined by combining existing elementary or composite services, that are in turn offered as high-level services or processes.

The Semantic Interoperability Problem

- *Service-oriented computing* offers *a technical means* for building cross-enterprise processes.

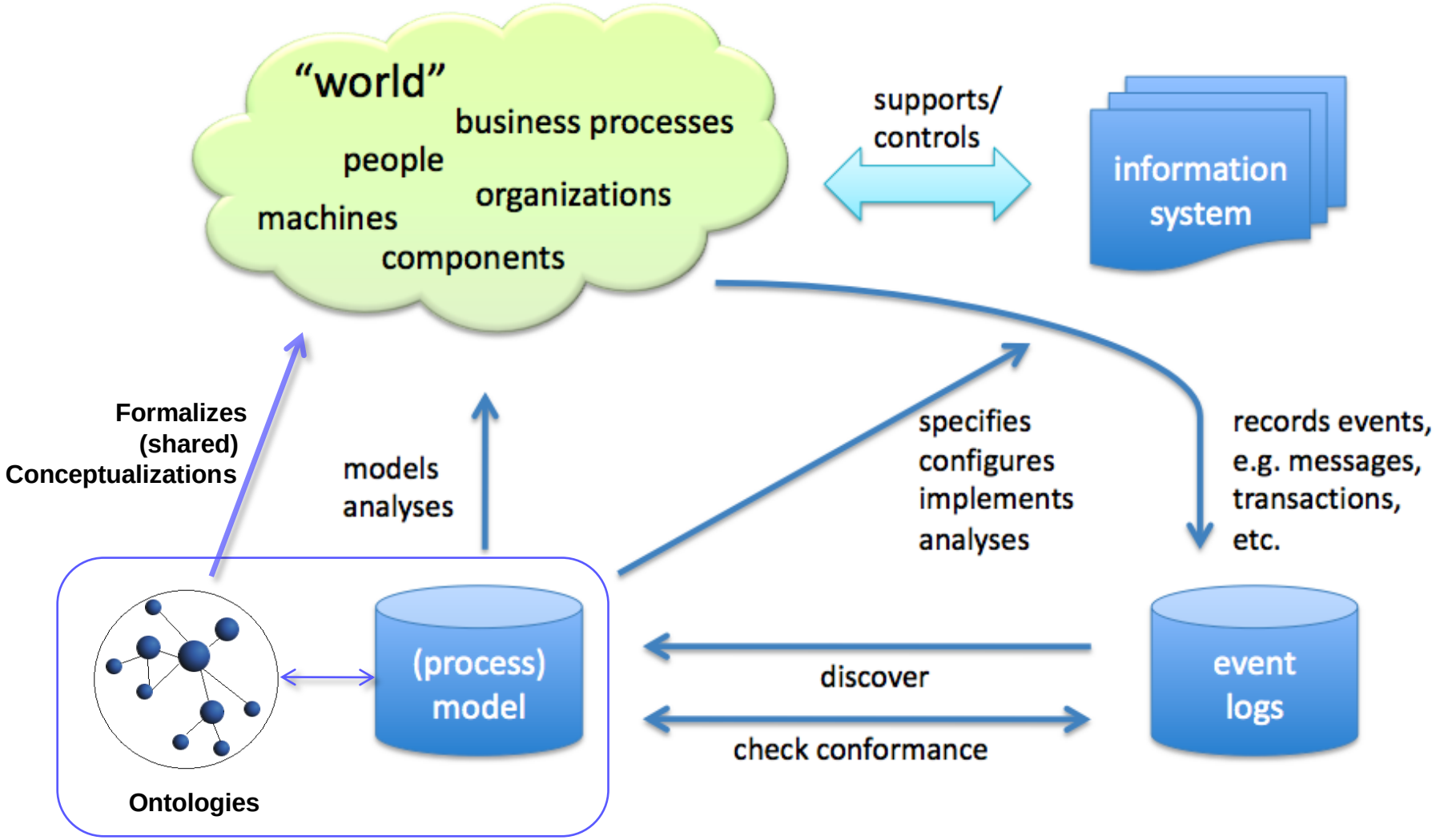
- However, the *semantic interoperability problem arises both at a data level and at a process level.*
  - BPs are built by using different tools, according to different business logics, and using different labels and terminology to denote activities and resources.
  - A common view of the business domain should be used…
  - …together with descriptions of the local BPs according to such an agreed common view.

Semantic BPM

- Promising solutions for the enhancement of BP management tools from the area of the Knowledge Representation to ease:
  - interoperability between software applications and reuse/exchange of knowledge between human actors
  - automation in the specification, analysis, implementation and monitoring
  - same principles at the basis of the Semantic Web vision
  - see, e.g., the SUPER (http://www.ip-super.org/), COIN (http://www.coin-ip.eu/) and PLUG-IT (http://plug-it.org/) European projects.

- Shared vocabularies (aka **Ontologies**) to describe processes
  - Input / output
  - Involved resources (*data models, organizational models*)
  - Goal
  - Pre-conditions and effects
  - Non-functional information (e.g., QoS)
  - See, e.g., OWL-S [3] and WSMO [4]

On the role of models…again



What is an Ontology?

- Ontology: the philosophical discipline
  - Study of ***what there is***
  - Study of the ***nature*** and ***structure*** of "reality"

> ***A (philosophical) ontology*** *is* a structured system of entities assumed to exists, organized in categories and relations.

- Computational ontologies:

> Specific (theoretical or computational) artifacts expressing the ***intended meaning*** of a ***vocabulary*** in terms of ***primitive*** categories and relations describing the ***nature*** and ***structure*** of a ***domain of discourse***

...in order to account for the competent use of vocabulary in real situations!

Gruber: "Explicit and formal specifications of a ***conceptualization***"

Ontology Languages in the Semantic Web

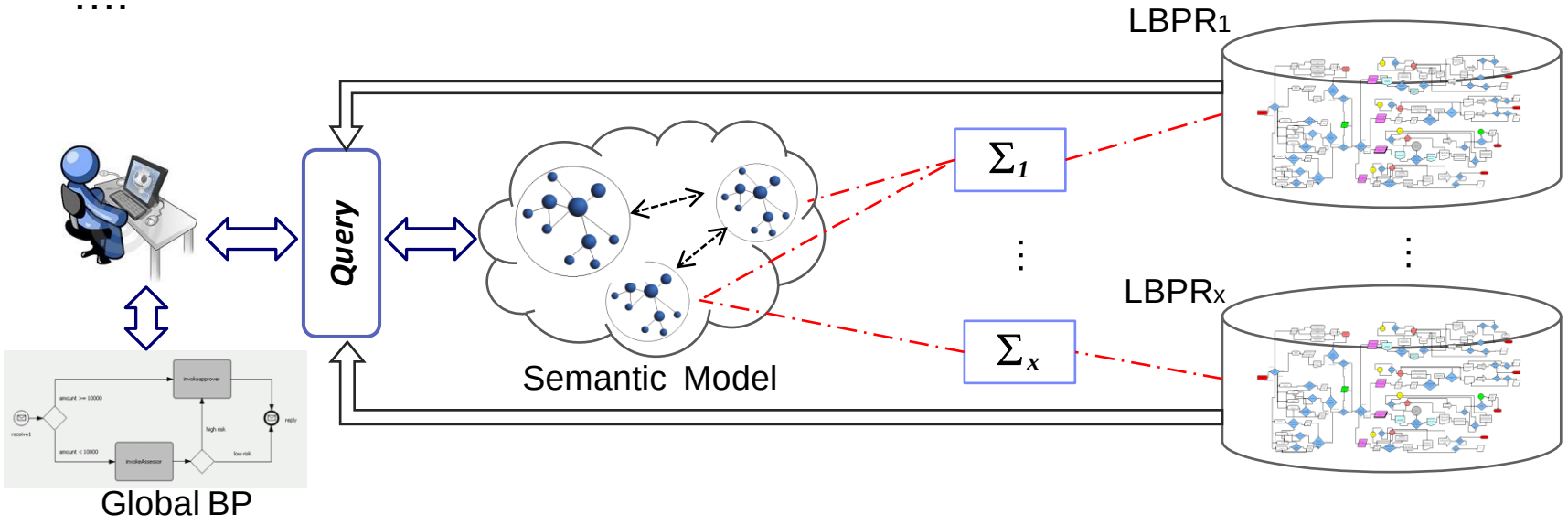
- RDF
  - Generic mechanism for describing resources
  - Data Model based on *statements* in the form of triples $<subject,predicate,object>$
- RDFS
  - An RDF vocabulary to describe other RDF vocabularies
  - Introduces hierarchies and domain and range restrictions on properties
- OWL
  - Ideally, an extension of RDFS with new modeling primitives (strong relationship with Description Logics)
  - Several sub-language. Among them, **OWL-RL:**
    - subset designed for practical implementations using rule-based techniques
    - semantics is an upward-compatible extension of RDF and RDFS
    - axiomatisation of the OWL 2 RDF-Based Semantics (OWL 2 RL/RDF rules) in the form of first-order implications

$$<?o,rdf:type,?x>, <?x,rdfs:subClassOf,?z> \longrightarrow <?o,rdf:type,?z>$$

Ontologies… for what?

Reasoning with BPs through a suitable semantic model used for the annotation of BP Repositories

- **Query** & retrieval
- Similarity reasoning
- Composition
- ….



Reasoning on Semantically Enriched Business Processes

Motivations and Goal

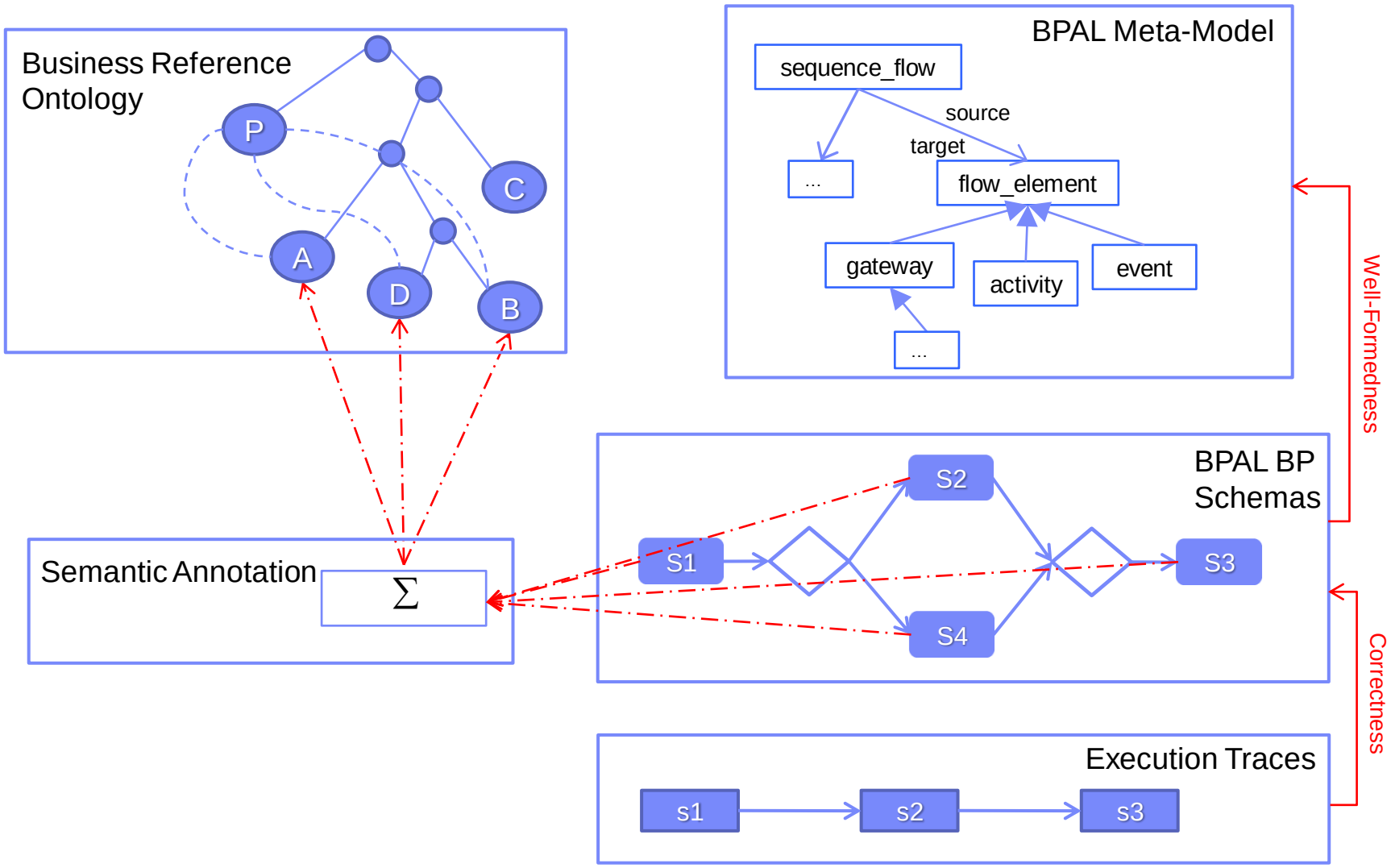
- Several open issues regarding
  - the synergy between workflow languages and ontologies:
    - execution semantics (enactment, correctness of BP executions,…)
    - verification (deadlocks, livelocks, …)
    - taxonomic reasoning
    - …
  - the accomplishment of reasoning services involving both these components:
    - business rules (modeling and compliance verification)
    - querying & retrieval (reuse, composition, …)
    - …

- Our goal is to provide a uniform and formal representation of both the workflow-related and the ontology-related (domain) knowledge.

BPAL Framework

- BPAL (Business Process Abstract Language)
  - A declarative modeling method to capture the procedural knowledge of a BP
  - Based on widely accepted modeling languages (i.e., BPMN)
  - Provided with an explicit formalization of the meta-model and execution semantics (suited for automated reasoning)
- Semantic Enrichment through Reference Ontologies
  - OWL-RL support (more or less Description Logic Programs)
- Formalization in Logic Programming
  - Uniform and formal representation
  - Support by tools developed in the area of logic programming
  - A BPAL specification (meta-model, schema and trace semantics) can be queried by any Prolog system (no need for ad-hoc compiler)

Business Process Knowledge Base

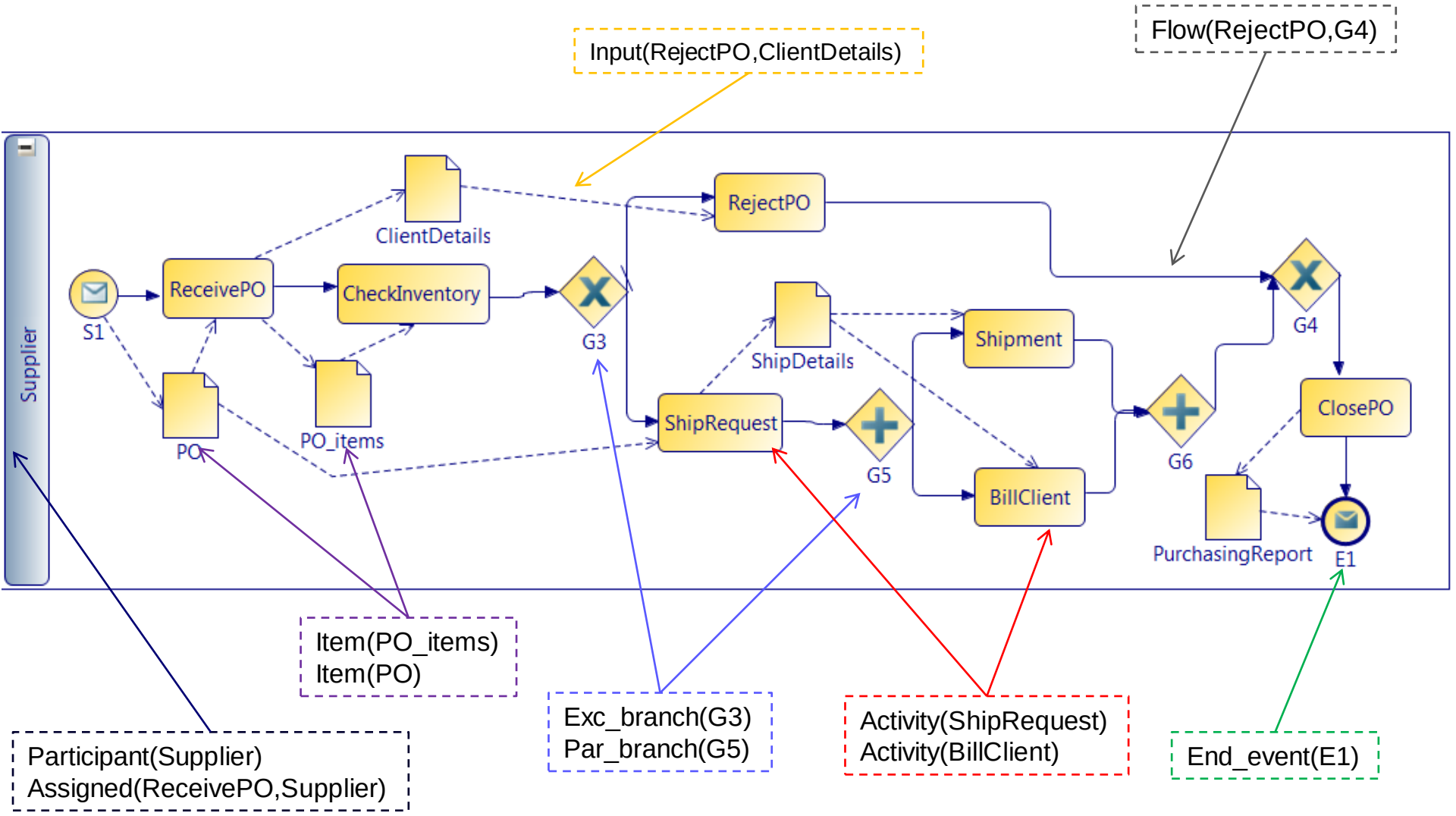


BPAL

- BPAL [3] is a logic-based language (i.e., a set of predicates and constants) conceived to provide a declarative modeling method capable of fully capturing procedural knowledge in a business process.
  - its core is based on BPMN 2.0 specification

- A BPAL business process schema (BPS) is specified by a set of ground facts of the form $p(C_1,...,C_n)$, where $C_1,...,C_n$ are constants denoting BPS elements (e.g., business activities, events, and gateways) and p is a BPAL predicate.

BPAL Overview



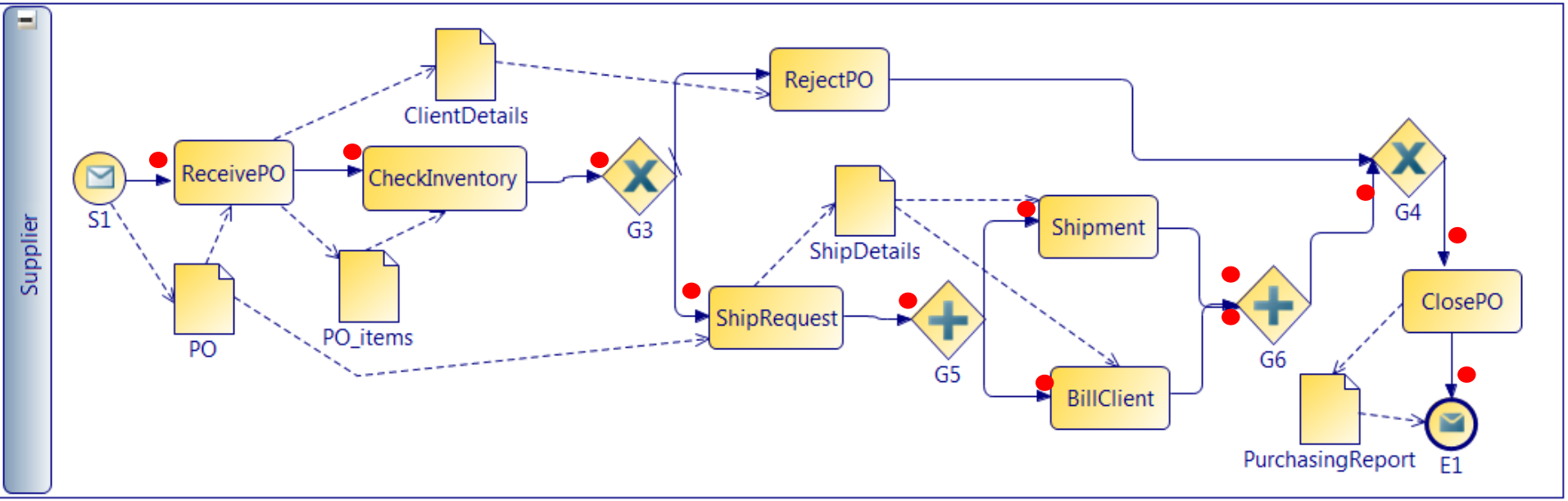
BPAL Meta-model

The BPAL Meta-model theory (***M***) formalizes a set of structural properties of a BPS, that at this level is regarded as a labeled graph:

- *Well-formedness,* defining how the constructs provided by the BPAL language can be used to build BPS correct from a syntactical point of view:
  - *local properties,* e.g., every activity must have at most one incoming and at most one outgoing sequence flow;
  - *global properties,* e.g., every flow element must lie on a path from the *start* to the *end.*
- *Structuredness*, of a (sub-)process*:*
  - each branch point is matched with a merge point of the same type, and such branch-merge pairs are also properly nested.
- *Reachability* between nodes;
- *Containment* of an element within a (sub-process);
- …

Execution Semantics

A process trace represents a possible execution of a business process, reflecting a sequence of token-transitions



- Start(FulfillPO)
- Complete(ReceivePO)
- Complete(CheckInventory)
- Choice(G3,ShipRequest)
- Complete(ShipRequest)
- Fork(Shipment,BillClient)
- Complete(Shipment)
- Complete(BillClient)
- Synch(Shipment,BillClient)
- Merge(G6)
- Complete(ClosePO)
- End(FulfillPO)

Trace Theory

- The execution semantics of a BPS is formalized by the theory ***T*** , in terms of state transitions:

$$\begin{aligned} \text{trans}(S,\text{complete}(A),Z) \leftarrow & \\ & \text{activity}(A) \wedge \\ & \text{holds}(\text{token}(A1,A),S) \wedge \\ & \text{flow}(A,B) \wedge \\ & Z = (S - \{\text{token}(A1,A)\}) \cup \text{token}(A,B). \end{aligned}$$

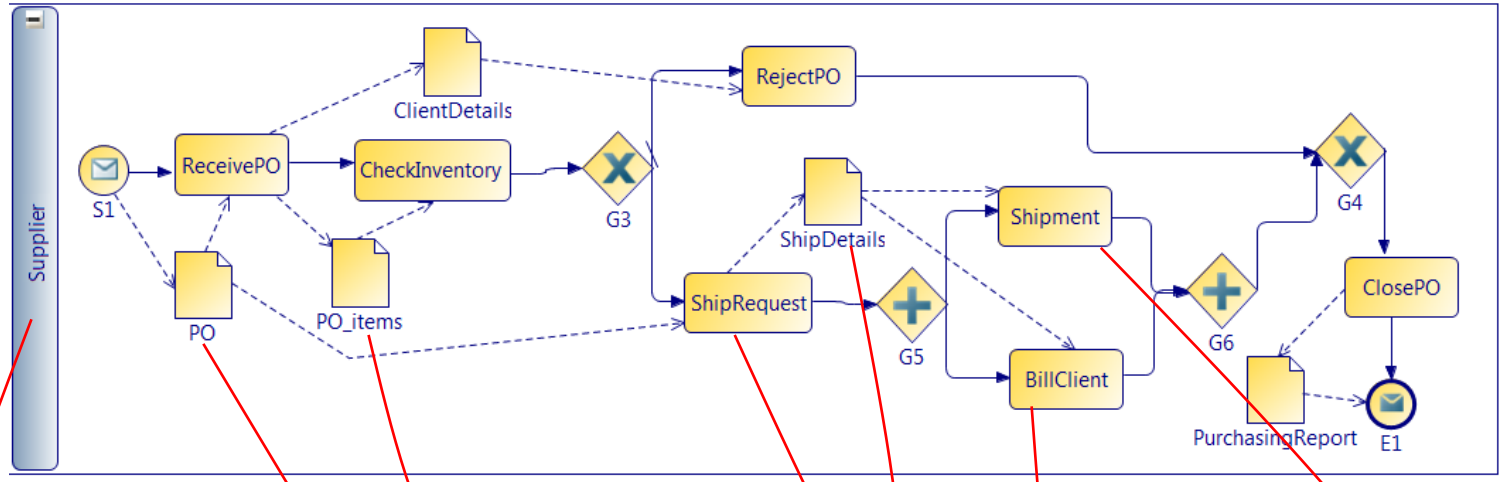
  - *TR* is *trace* from S to Z if $trans(S, TR_1, Z_1) \wedge trans(Z_1, TR_2, Z_2) \wedge \ldots \wedge trans(Z_n, TR_{n+1}, Z)$ and $TR = [TR_1, TR_2, \ldots, TR_{n+1}]$.

- ***T*** can be used to:
  - verify the correctness of a trace w.r.t. a given BPS
  - generate the set of correct traces given a BPS
  - verify ordering properties (i.e., dependency constraints)

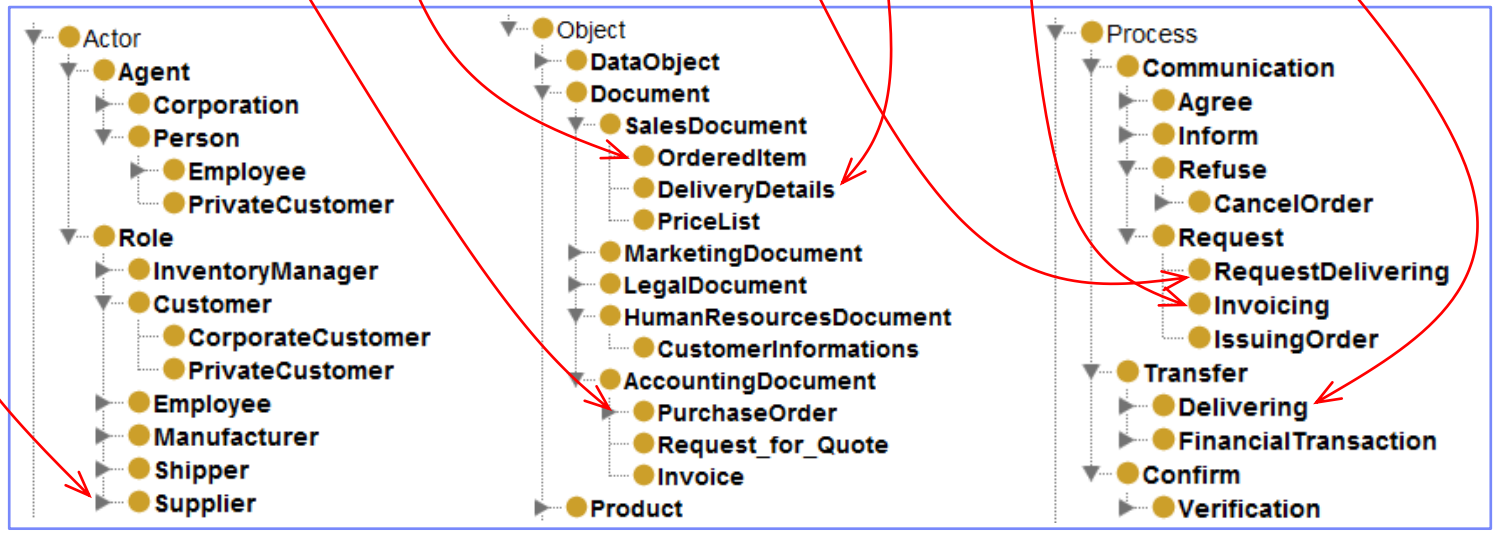
Behavioral Properties

- In theory
  - Exploration of the state space
  - Model Checking (CTL)
  - Very Expensive
- In practice
  - Some relevant properties can be verified with ad-hoc strategies, without state space exploration
    - *precedence(a,b) if b is executed then a has been previously executed*
    - *response(a,b) if a is executed then b will be executed after*
    - *mutex(a,b) a and b are never both executed*
    - *coexistence(a,b) neither a nor b are executed, or they are both executed*

Semantic Annotation



BP Schema



Business Reference Ontology (BRO)

Annotated Business Process

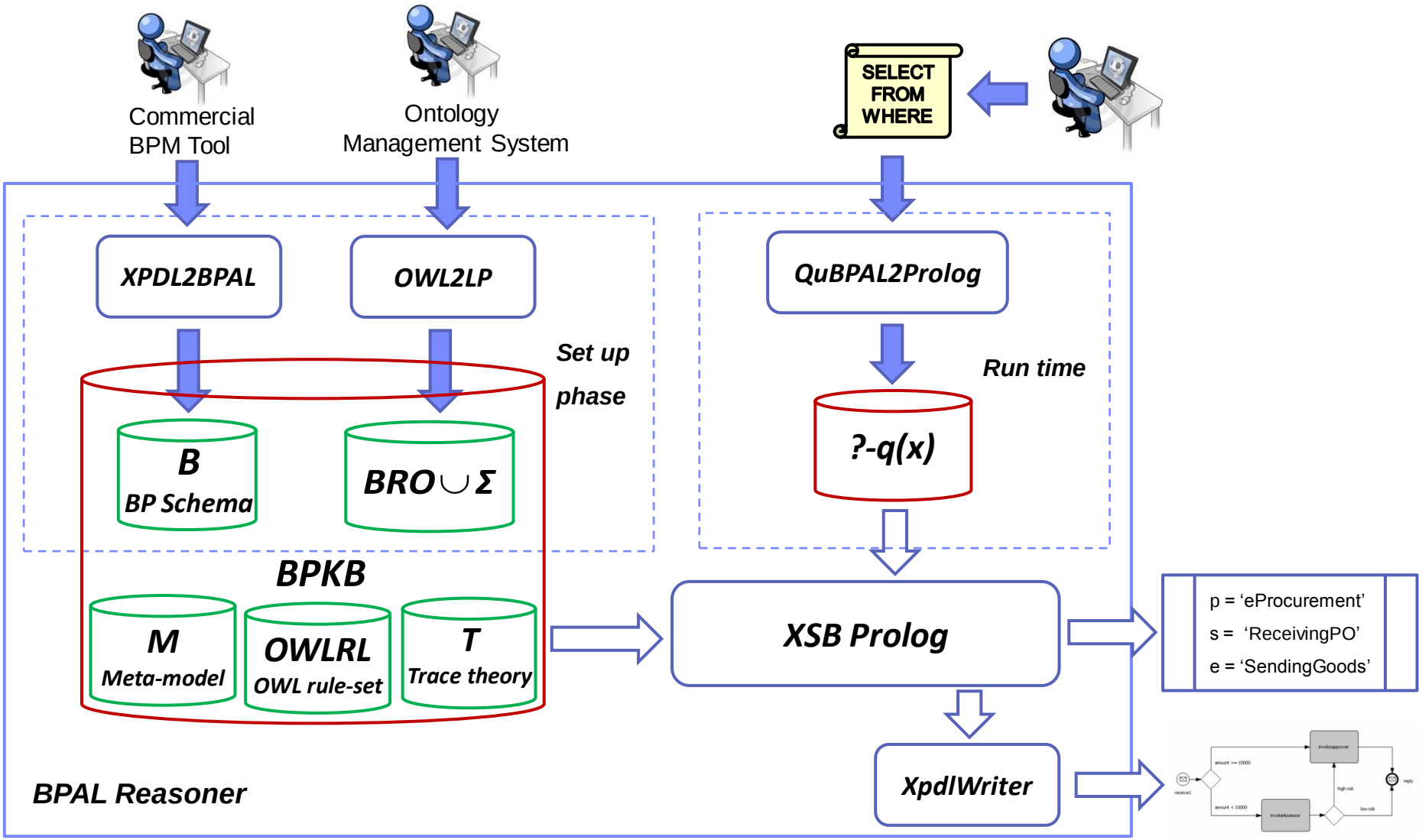
```
<rdf:Description rdf:about="bps:ReceivePO">
    <rdf:type rdf:resource="bpal:Activity"/>
    <bpal:input rdf:resource="bps:PO"/>
     <bpal:model_ref>http://acme/ACME.xpdl#_123</bpal:model_ref>
     ….
</rdf:Description>

<rdf:Description rdf:about="bps:BillClient">
    <rdf:type rdf:resource="bpal:Activity"/>
    <bpal:sigma rdf:resource="bro:Invoicing"/>
    <bpal:assigned rdf:resource="bps:Supplier"/>
     ….
</rdf:Description>

<rdf:Description rdf:about="bps:PO">
    <rdf:type rdf:resource="bpal:Item"/>
     <bpal:sigma rdf:resource="bro:PurchaseOrder"/>
     ….
</rdf:Description>

<rdf:Description rdf:about="bps:Supplier">
    <rdf:type rdf:resource="bpal:Participant"/>
     ….
</rdf:Description>
```

Reasoning on the BPKB

- The BPKB [4] can be translated to a Logic Program to model and reason with:
  - process structure (BPAL schema + Meta-model): flow elements (activities, events, gateways) and their relationships (sequence flows);
  - process executions (BPAL schema + Trace semantics): behavior at execution time and properties regarding the temporal sequencing of activities in the set of correct traces;
  - domain knowledge (Ontology + Semantic Annotation): domain entities (processes, actors, object) and their relationships.

- The BPAL framework provides:
  - a reasoning engine, based on Logic Programming, that operates on a BPKB;
  - a BP query language, developed on top of the reasoning engine;
  - a verification mechanism, tightly connected to the latter.

BPAL Reasoner



QuBPAL

- A SELECT-FROM-WHERE query language for the BPKB
  - translation into logic programs, nested and disjunctive queries

- **SELECT** statement: output of the query evaluation
  - a sequence *?x** of variables occurring in the WHERE statement
  - a BPS, denoted by the process identifier <*?bpId*>
  - a sub-process of a BPS, denoted by the triple <*?bpId,?start,?end*>

- **FROM** statement: the process(es) from which data is to be retrieved
  - a non empty sequence of BP schemas or sub-processes (<*bpId*>|<*bpId,start,end*>)$^+$

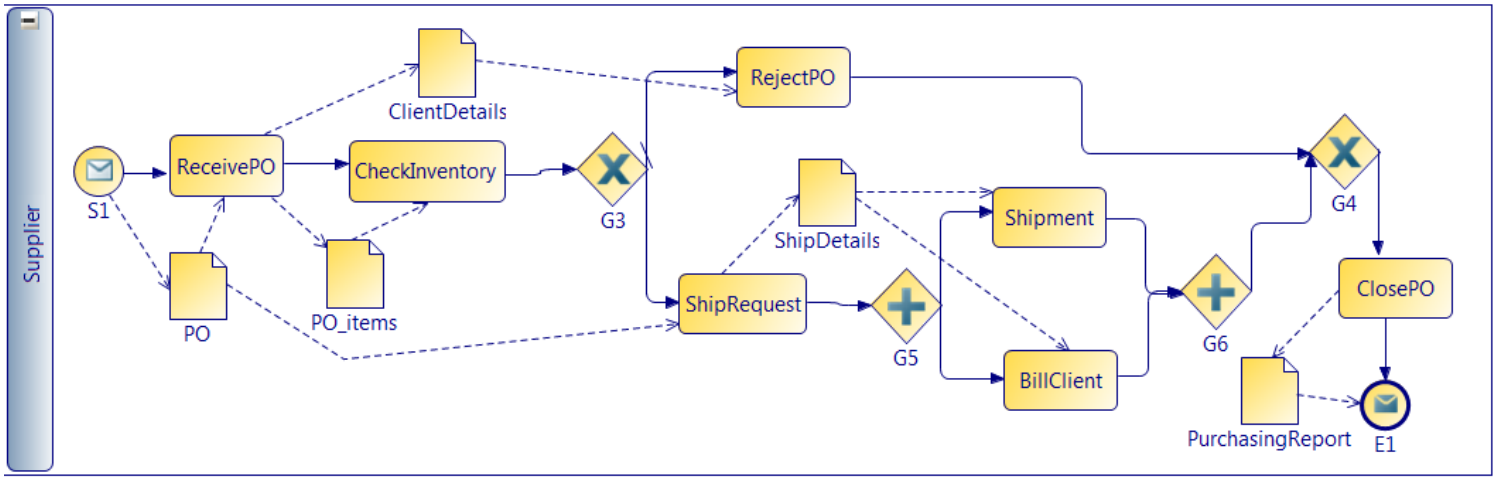
- **WHERE** statement: a sentence built from
  - the set of the predicates defined in the *BPKB*;
  - the connectives AND, OR, NOT, and the predicate = with the standard logic semantics;
  - another QuBPAL query, to allow nested queries.

- For the arguments used in the query, *bpsEl::conc* stands for "*bpsEl* is annotated with *conc*"

Query Example

Retrieve any process where a purchase order is processed and that provides services for the invoicing and the delivering of goods.

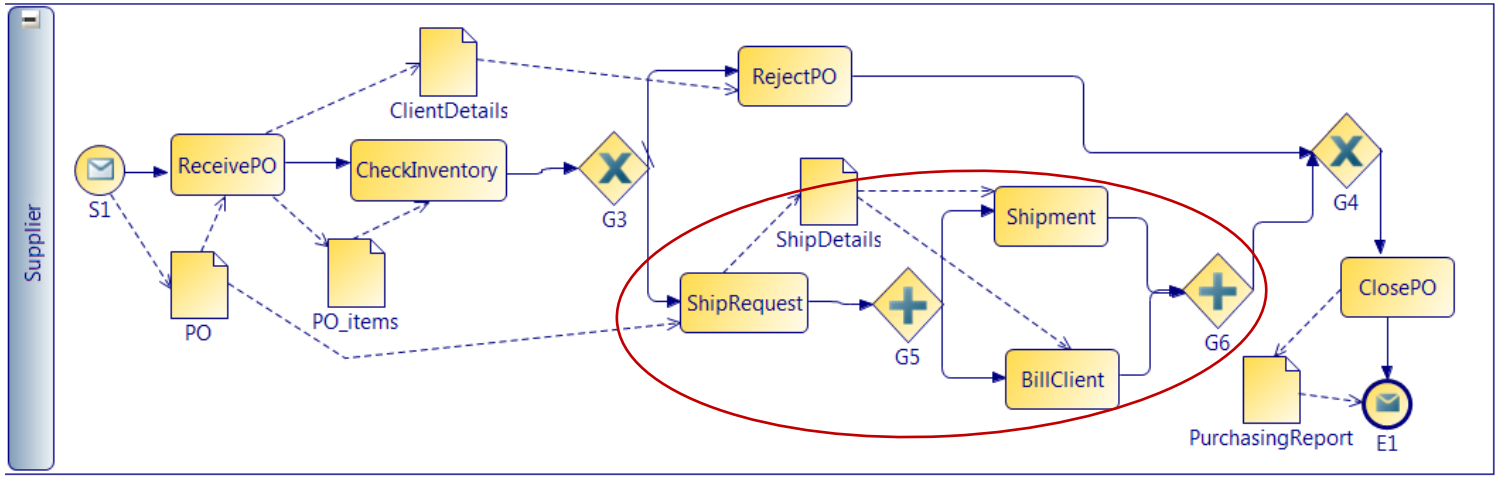
SELECT <?p>
FROM *
WHERE belongs(?a1,?p) AND input(?a1,?po::bro:PurchaseOrder) AND belongs(?a2::bro:Invoicing,?p) AND belongs(?a3::bro:Delivering,?p)



Query Example

Retrieve any sub-process that i) starts with an activity that processes a purchase order, and ii) both a delivering and an invoicing are eventually executed.

SELECT <?p,?s,?e >
FROM *
WHERE input(?s,?po::bro:PurchaseOrder) AND response(?s,?a1::bro:Invoicing,?p,?s,?e) AND response(?s,?a2::bro:Delivering,?p,?s,?e)



Students' Project Proposals

- Development of an Eclipse Plug-in for the management of the BPKB
  - Current work-in-progress
- Similarity Reasoning
  - Automatic support for annotation
  - Similarity measures for processes
  - Adopt/adapt ontology matching techniques
- Query processing / optimization
  - Currently a simple algorithm for the re-ordering of literals is implemented
- Graphical editor for QuBPAL queries
- Support for other standard BP modeling languages (e.g., BPEL)
  - Mapping from/to BPAL

References

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Thanks for your attention,
any question?