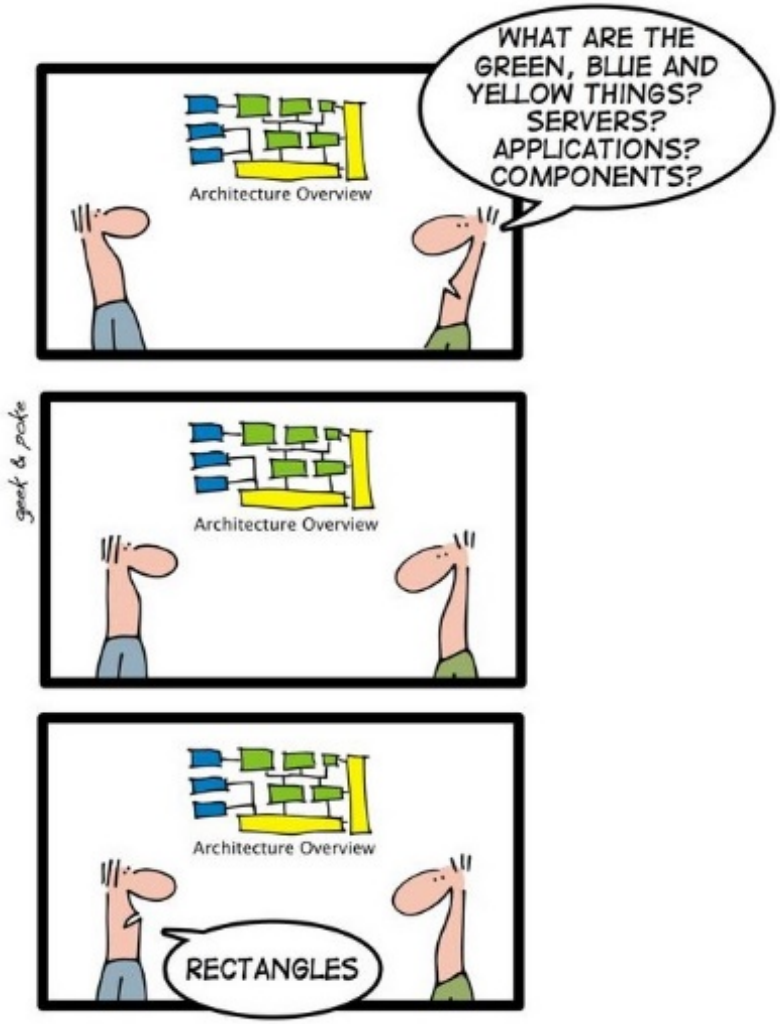
Ontology-based Metamodeling

Knut Hinkelmann

Making the Knowledge in Models explicit



- Humans «know» the meaning of the modeling objects.
  - Example: Process Modeling

    «Cook pasta» is a task about preparing food
- The objective is to represent the knowledge so that it can be interpreted by a system for decision making and problem solving

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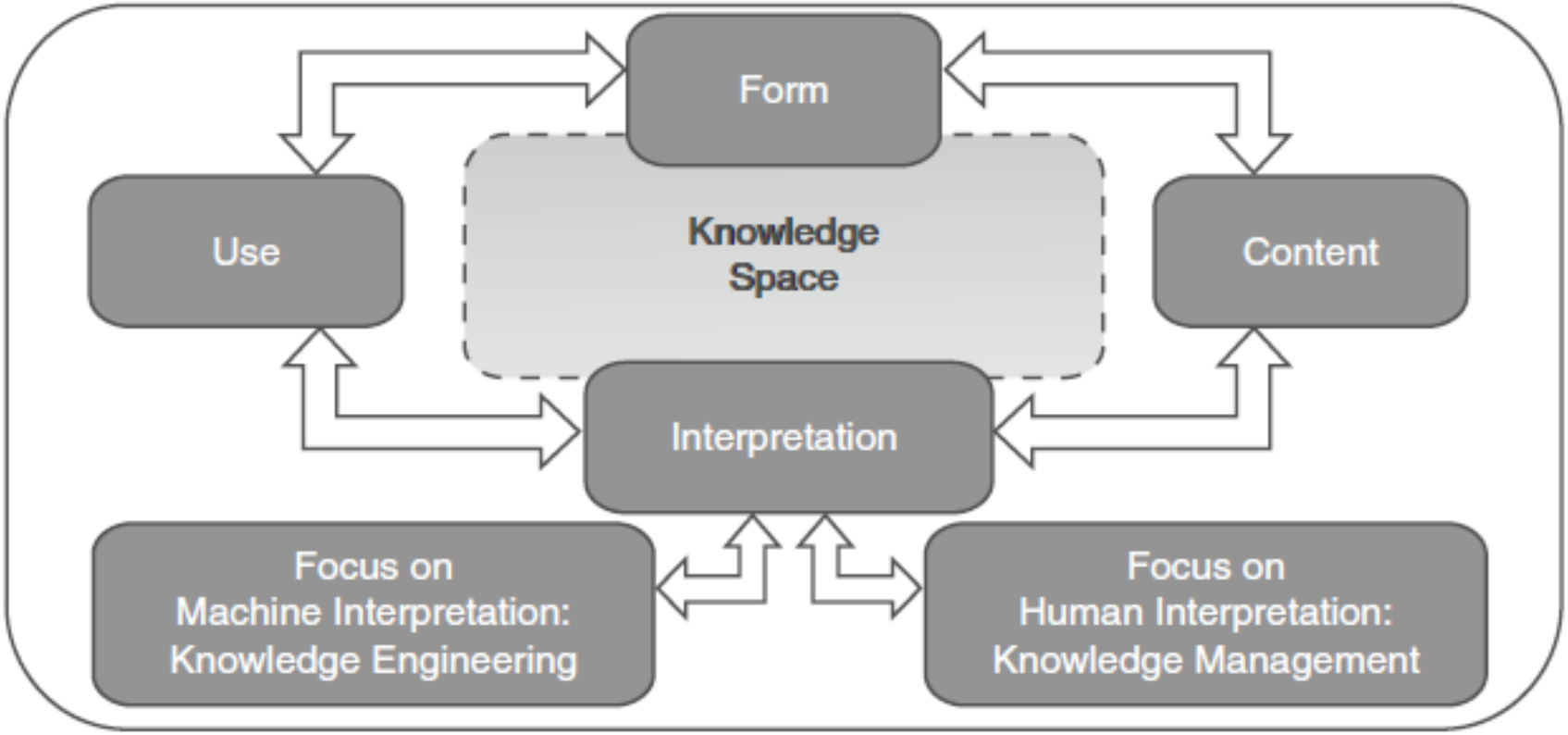
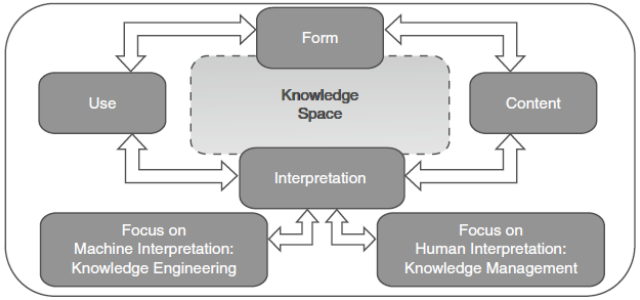
Dimensions of a Knoweldge Space



Dimensions of the Knowledge Space



Form: modeling language

Content: model information, represented in the description of elements

Use:

- process optimization requires knowledge about time and costs
- selection of a cloud service require knowledge about data and functionality

- ***Form***: Syntax and semantic of **modeling language**.
- ***Content***: **Domain** in which knowledge engineering is applied.
- ***Use***: Stakeholders and their concerns determine the relevant subset of the knowledge and reasoning
- ***Interpretation***: Graphical models typically are cognitively more adequate for human interpretation and ontologies can be interpreted by machines.

Semantic Lifting

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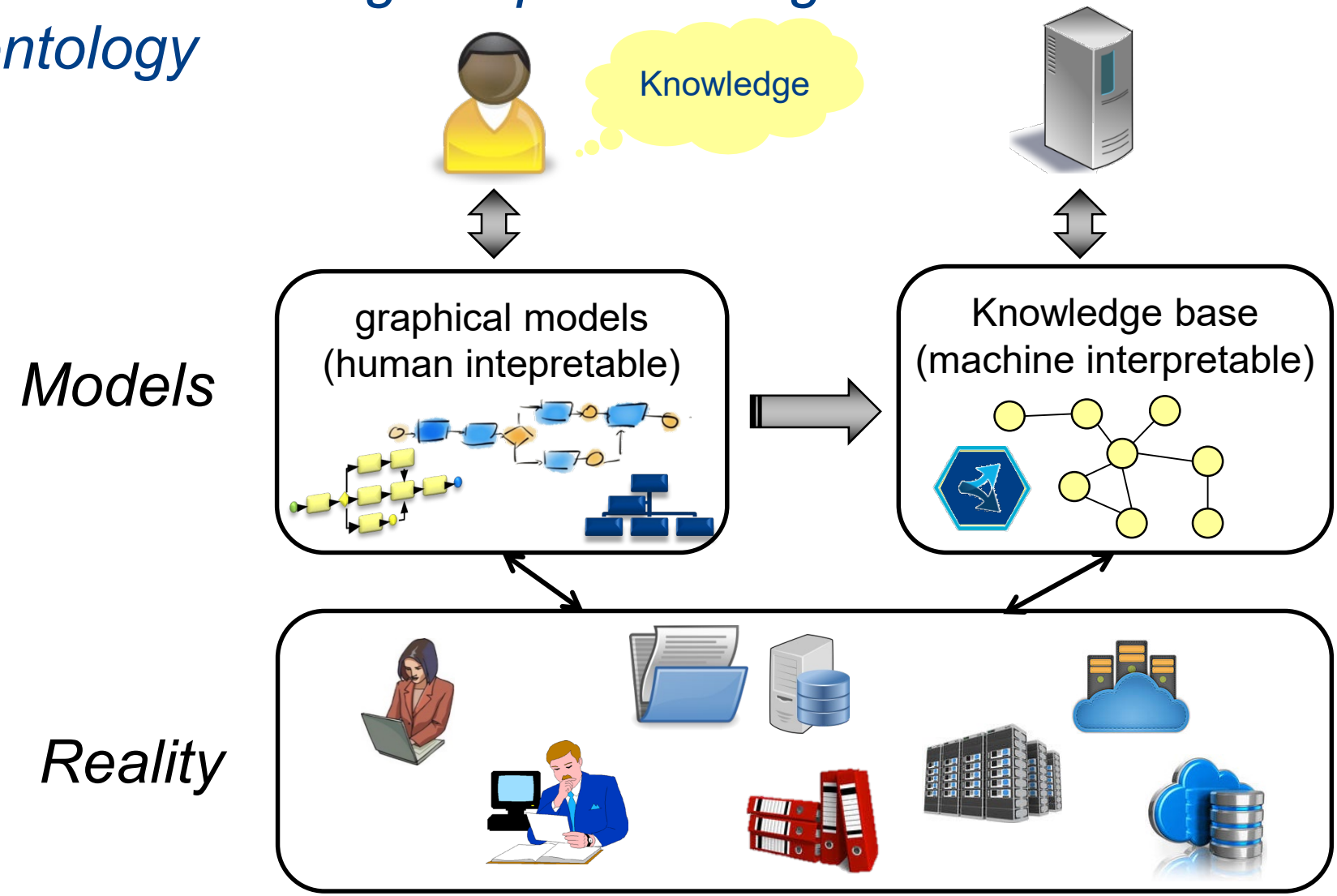
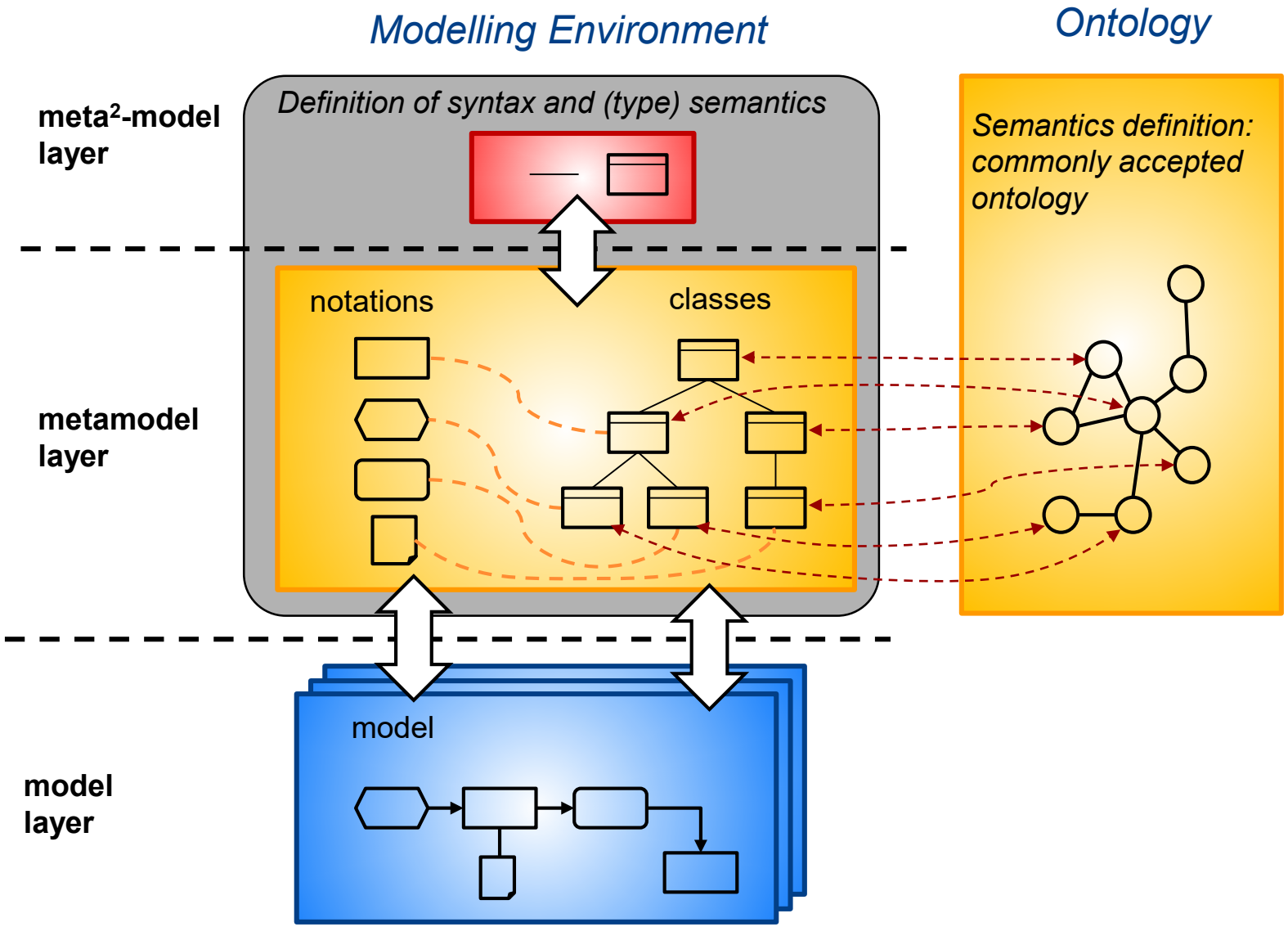
Semantic Lifting: Map knowledge of models into an ontology



Semantic Lifting

- Map knowledge of models into an ontology
  - Semantics: Classes of the metamodel are aligned with classes in the ontology
  - Interpretation: For each element in a model an instance of the ontology is created
  - Content: Model elements are annotated with domain knowledge from ontology
  - Inference of the ontology can be applied to the knowledge base



linguistic metamodelling: *syntax, structure, type semantics*

ontological metamodelling (lifting): *explication of type semantics*

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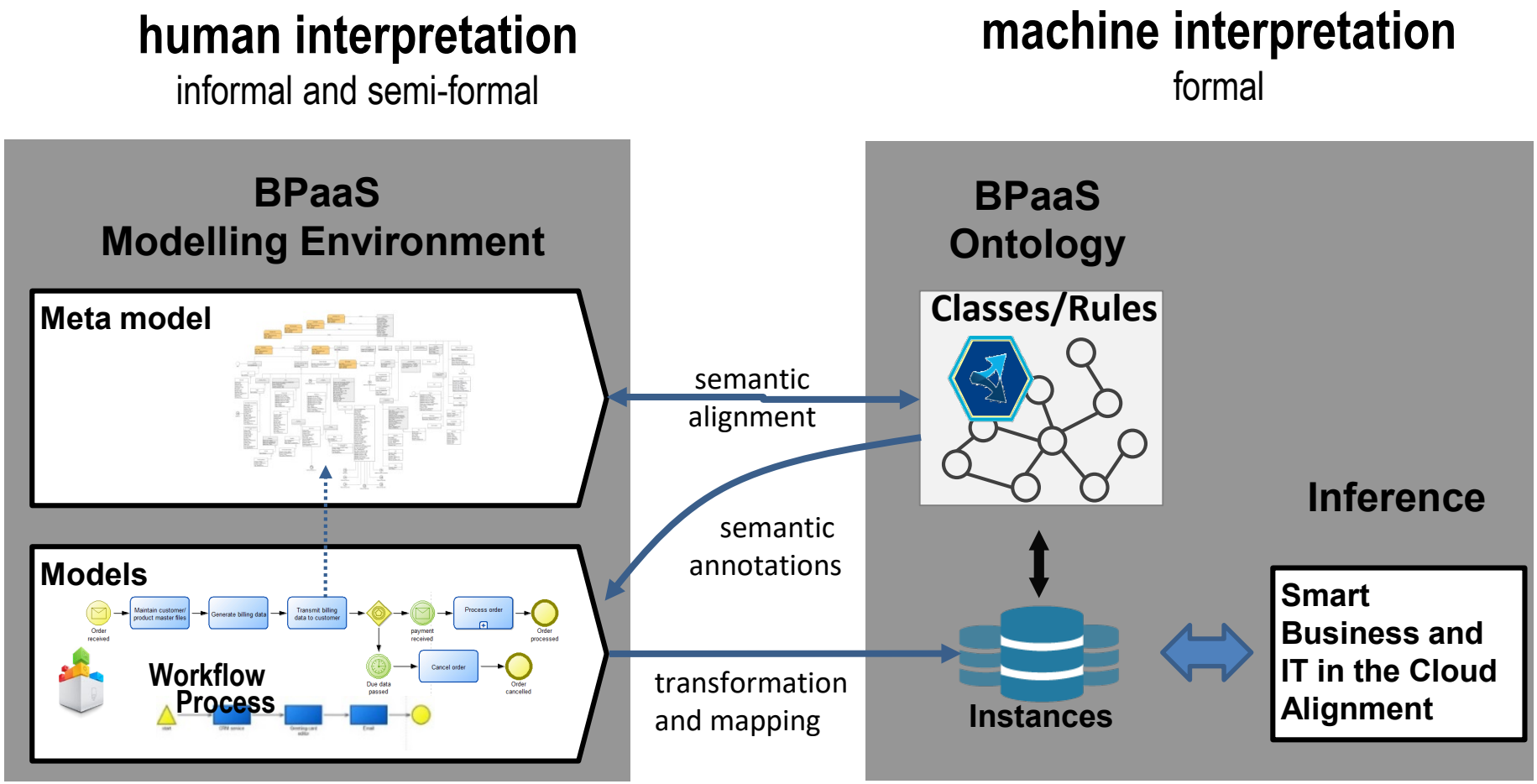
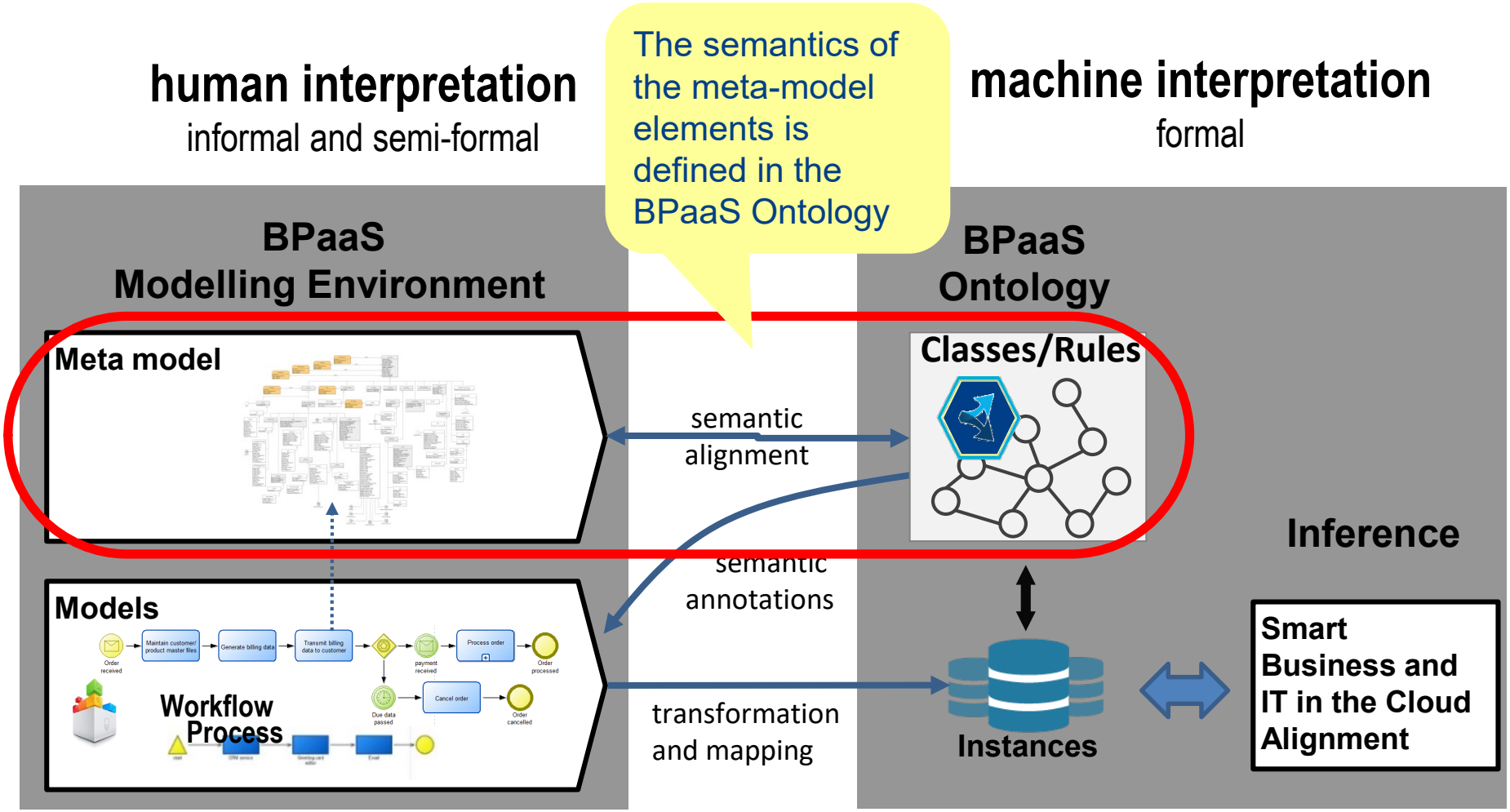
Example: Business Process as a Service



From: CoudSocket Project

Example: Business Process as a Service

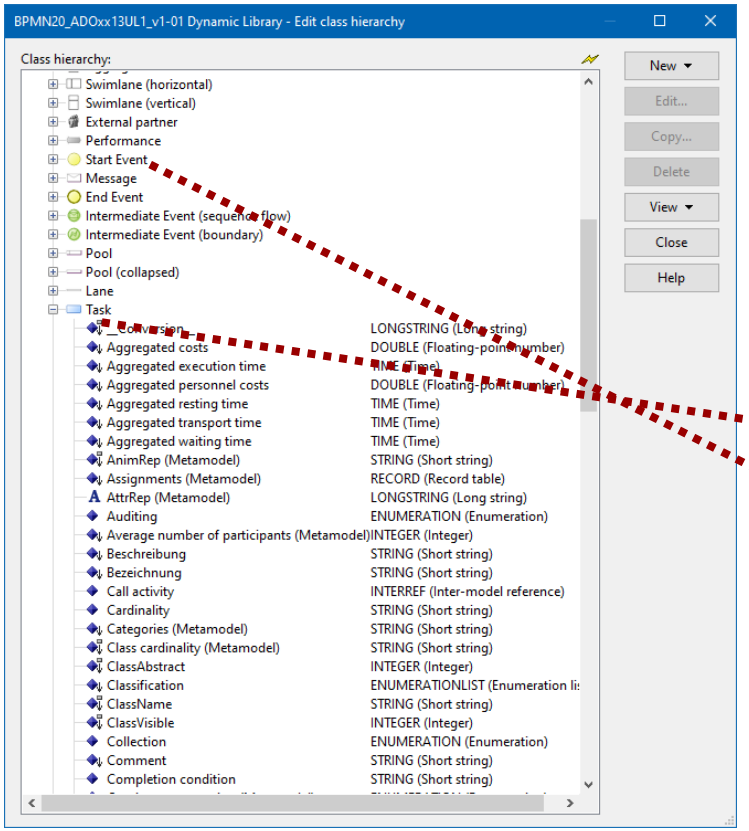


From: CoudSocket Project

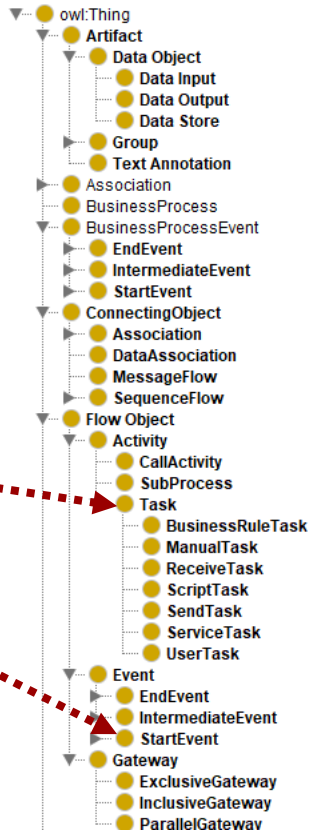
Semantic Alignment

The ontology contains classes for all modelling elements

BPMN Modelling Language in ADOxx



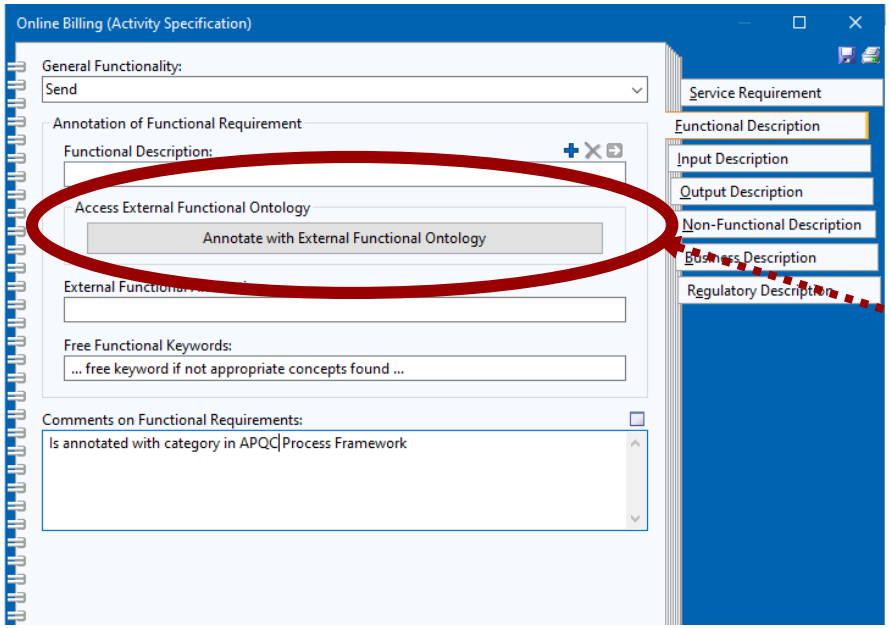
BPMN Ontology



Semantic Annotations

Annotate modeling elements with classes from the domain ontology

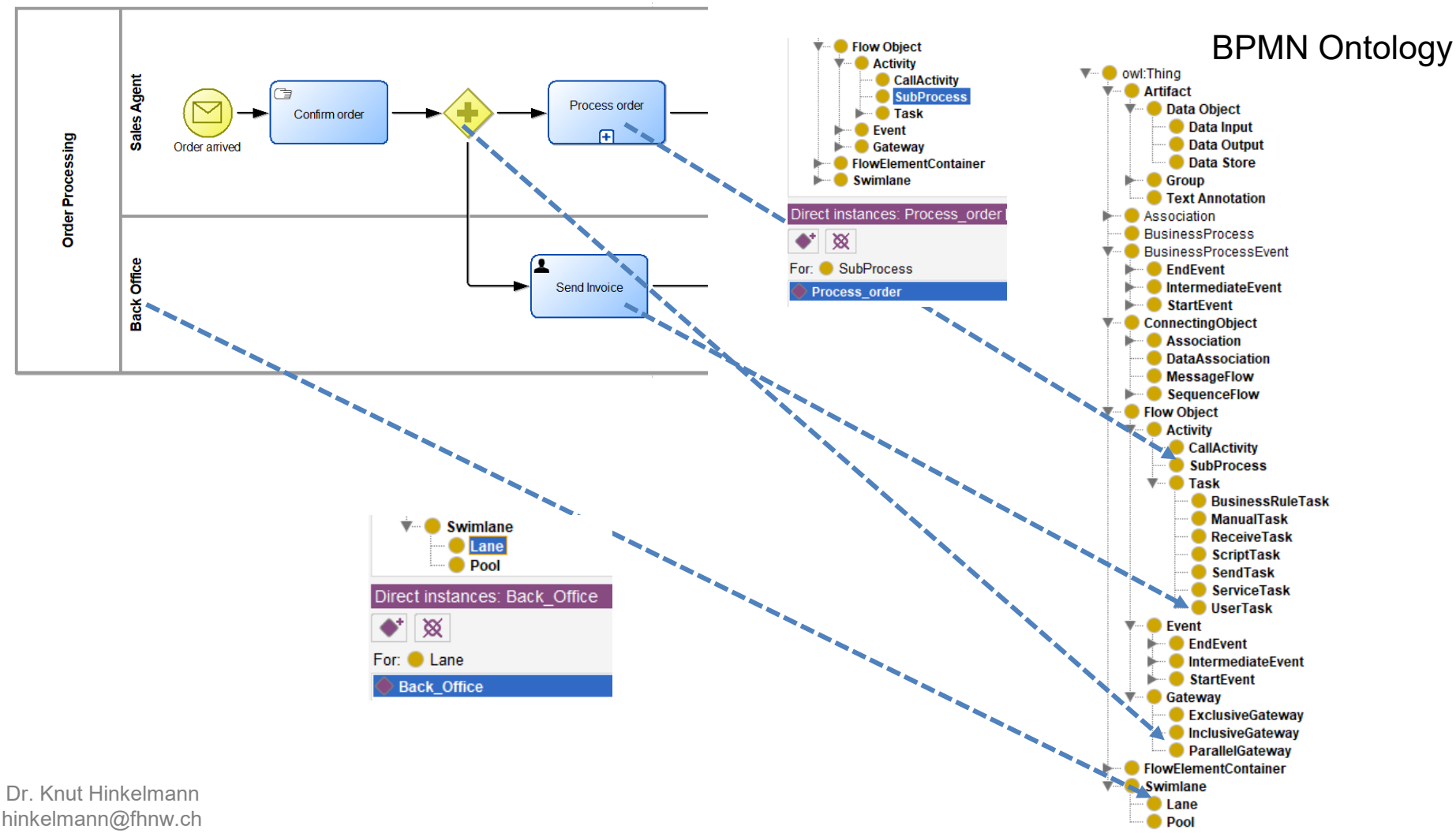
Example: Functionality of a Service



Ontology for APQC
Process Classification Framework

Transformation and Mapping

The model elements are exported as instances ontology classes



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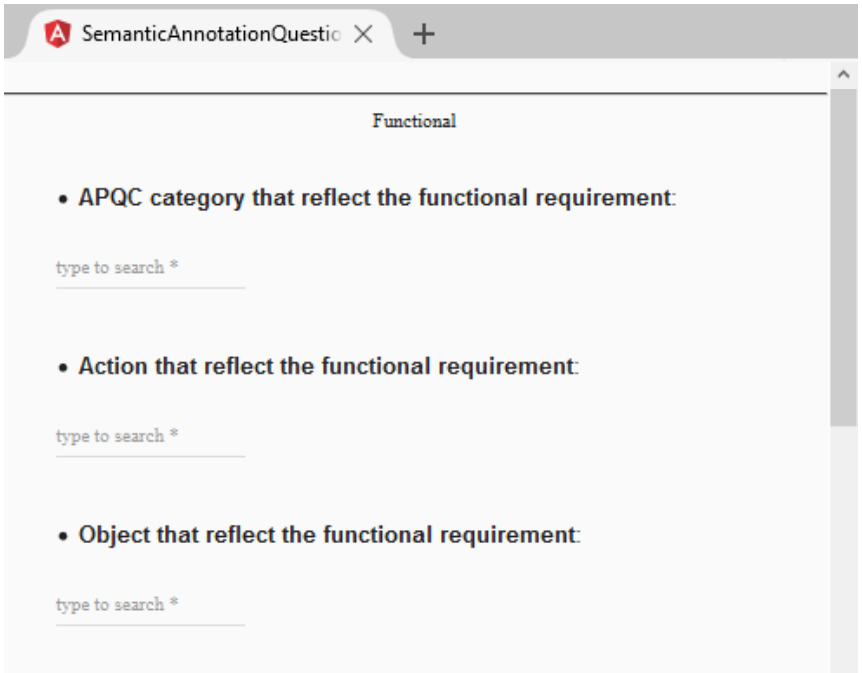
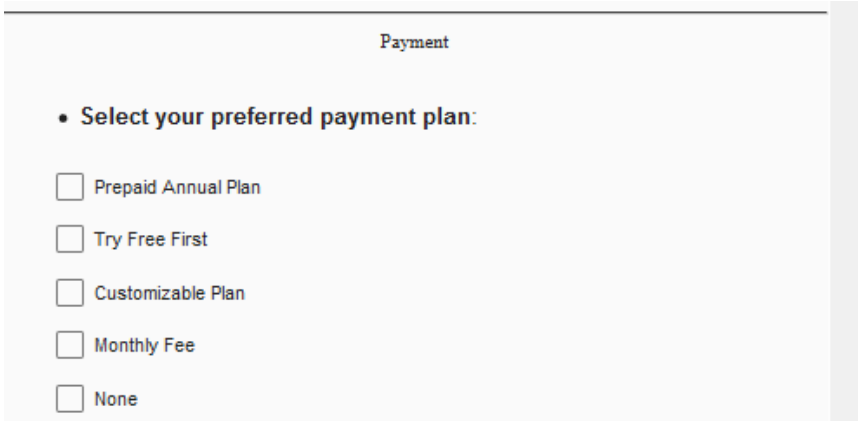
Inferencing: Cloud Service Selection

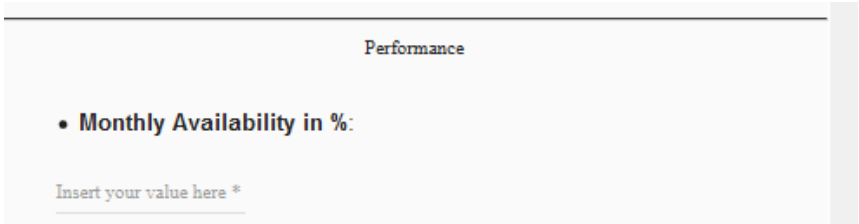
Cloud Service Selection

Functionality



Non-functional requirements





Thanks to Emanuele Laurenzi

Problems with Semantic Lifting

- Separate Environments for
  - Modelling
  - Knowledge Base (Inferencing)
- Inconsistency: Both metamodel and ontology must be aligned but are maintained independently:
  - Metamodel and ontology must represent the same semantics
  - Each change in metamodel must be reproduced in the ontology and vice versa
- Effort: After each change the model must be translated again into the ontology instances

Ontology-based Metamodelling

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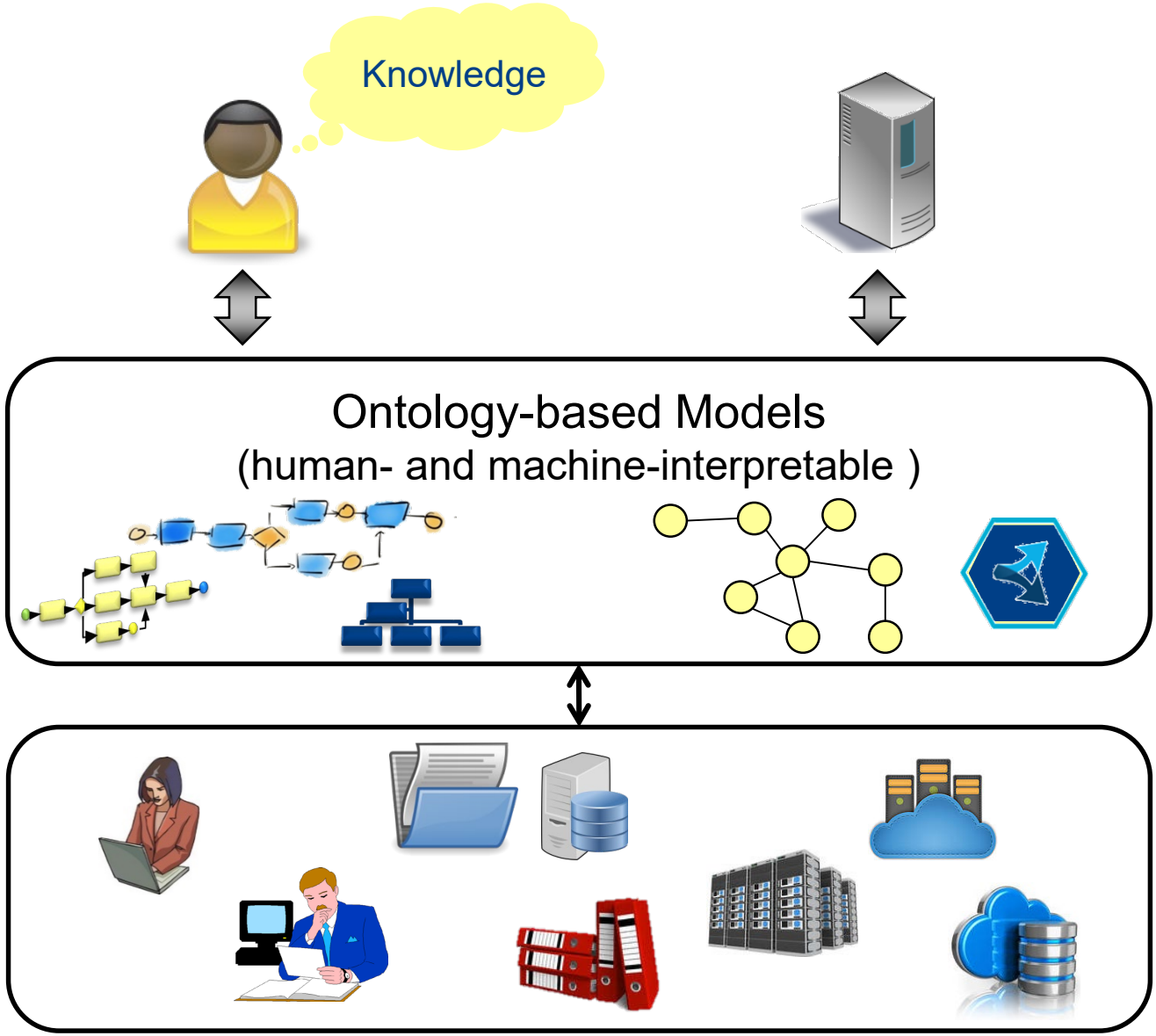
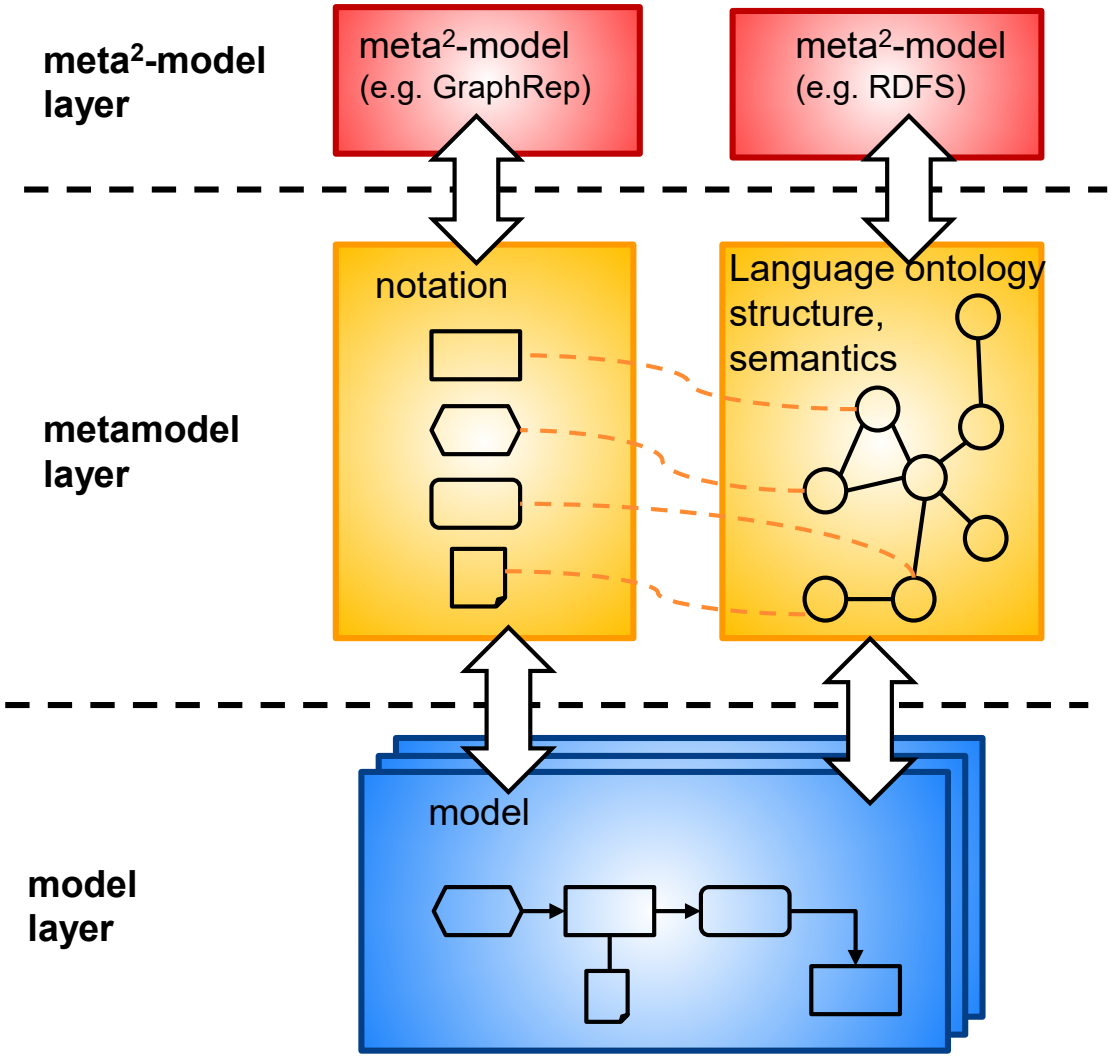
Objective



Models + Knowledge

Reality

Ontology-based Metamodeling (1): Metamodel is represented as an Ontology



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Modelling Language Ontologies

BPMN

- owl:Thing
  - Artifact
    - Data Object
      - Data Input
      - Data Output
      - Data Store
    - Group
      - GeneratingCustomerBillingData
      - ManagingCustomerRelationship
      - TransmittingBillingData
      - Wholeprocess_sendinvoice
    - Text Annotation
  - Association
  - BusinessProcess
  - BusinessProcessEvent
  - ConnectingObject
    - Association
      - DataAssociation
    - DataAssociation
    - MessageFlow
    - SequenceFlow
      - Sequence Flow With Decision
  - Flow Object
    - Activity
      - CallActivity
      - SubProcess
      - Task
    - Event
      - EndEvent
      - IntermediateEvent
      - StartEvent
    - Gateway
  - FlowElementContainer
    - Process
  - Swimlane
    - Lane
    - Pool

Archimate

- owl:Thing
  - ADMetaModel
  - ArchitectureModel
  - ArchitectureViewpoint
  - EnterpriseObject
    - Action
      - ApplicationFunction
      - ApplicationInteraction
      - BusinessBehaviourElement
        - BusinessEvent
        - BusinessFunction
        - BusinessInteraction
        - BusinessProcess
      - InfrastructureFunction
      - System Software
    - Active Structure Element
      - ApplicationComponent
      - BusinessActor
      - BusinessRole
      - CommunicationPath
    - Interface
    - Passive Structure Element
    - Service
  - InfrastructureElement
    - Network
    - Node
      - Device
      - System Software
  - Relationships
    - DynamicRelationships
    - OtherRelationships
    - StructuralRelationships
      - Access
      - Aggregation
      - Assignment
      - Association
      - Composition
      - Realisation
      - UsedBy
  - TopLevelElements
    - Event
    - Location
    - Time

lElement

er

lConnector

Combination

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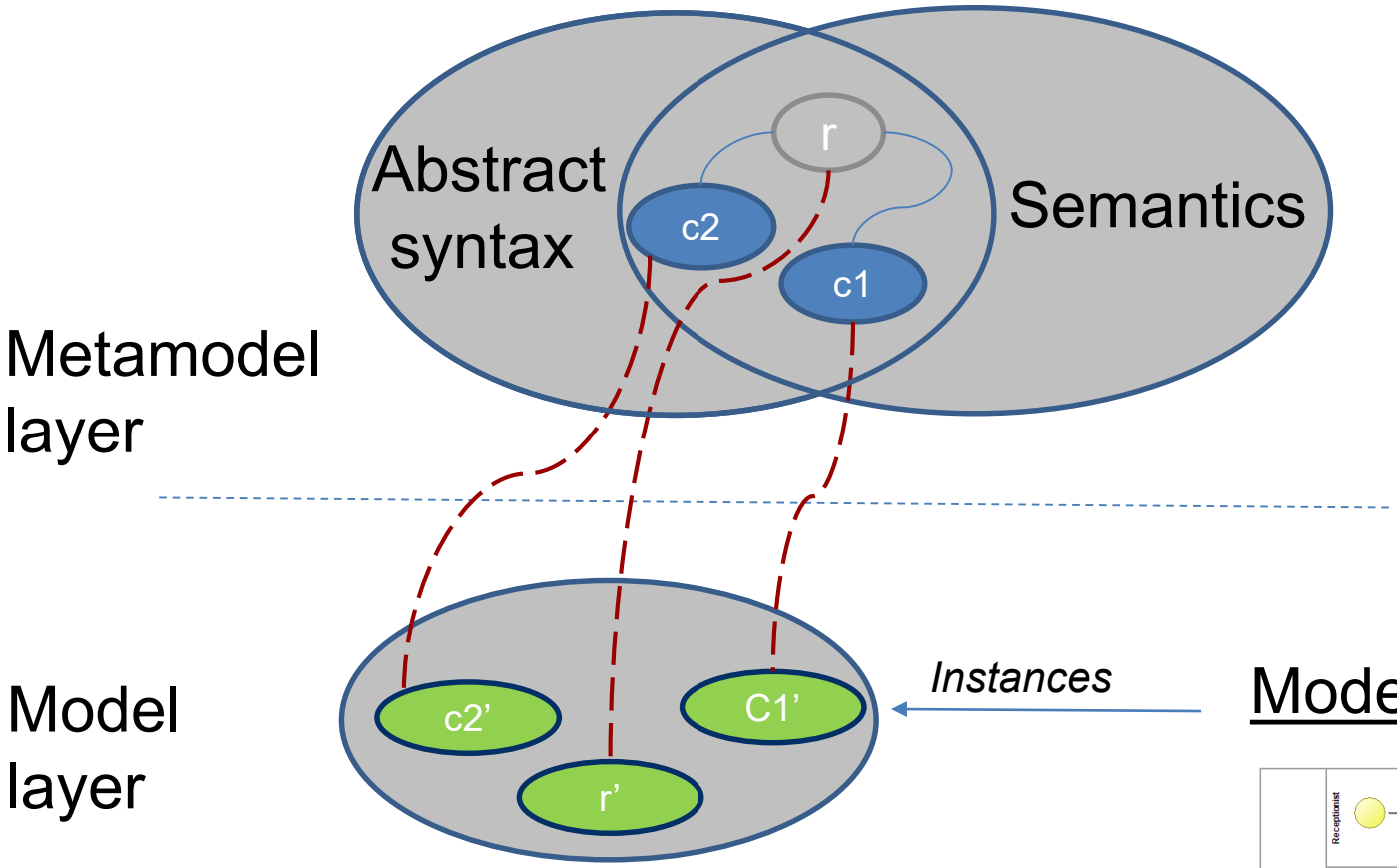
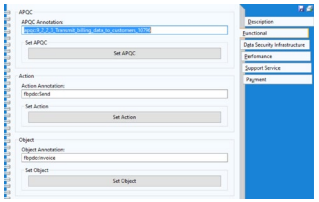
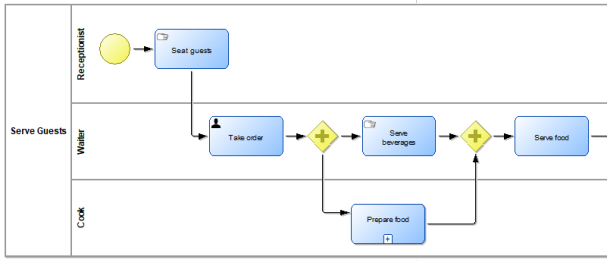
Ontology



Model





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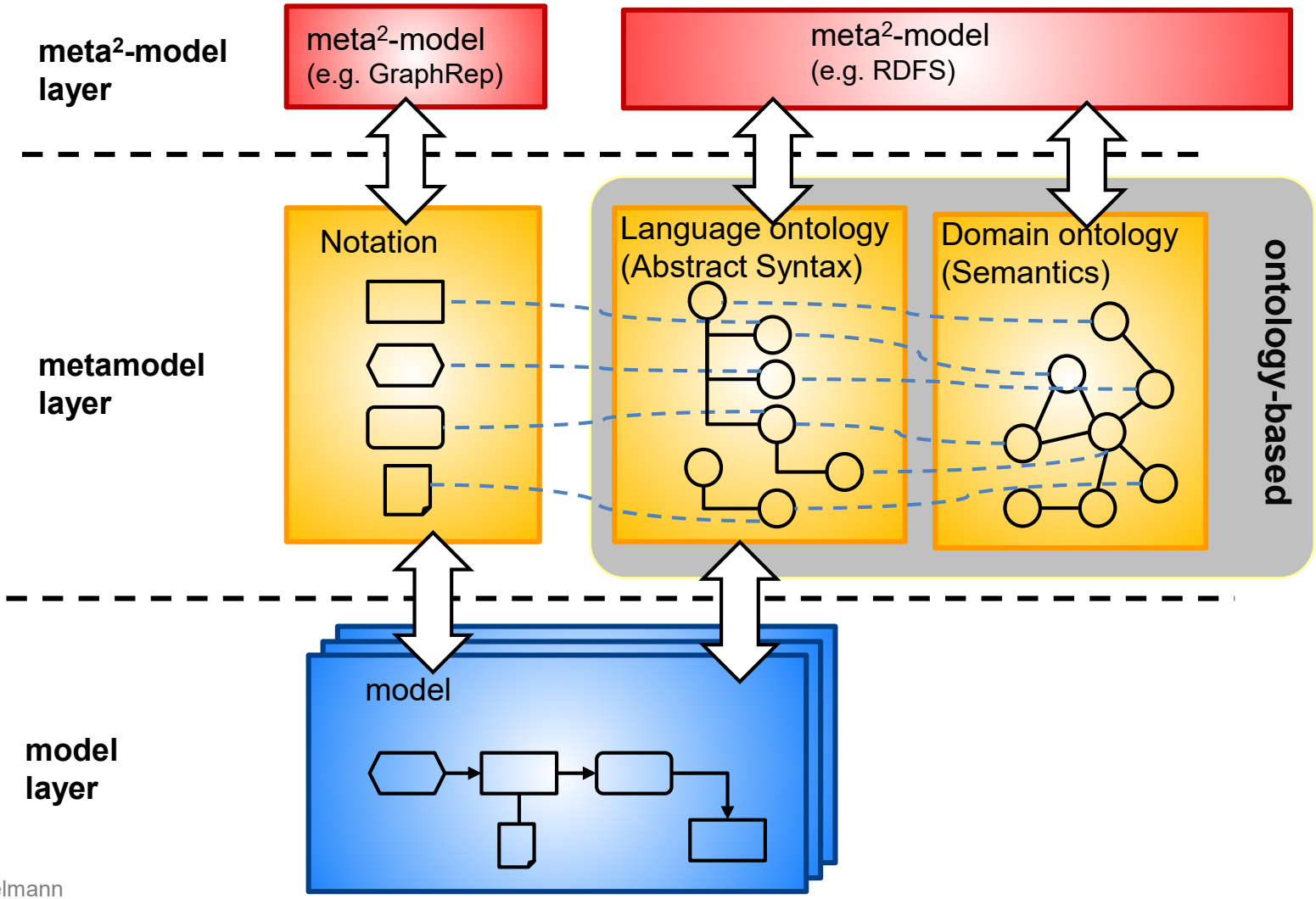
Ontology-based Metamodeling (2): Ontologies for Metamodel and Content



Domain Ontologies

Enterprise Ontology (excerpt)

- EnterpriseObject
  - Action
  - ActiveStructureElement
    - ApplicationComponent
    - BusinessActor
      - LegalEntity
      - OrganisationalUnit
      - Person
    - BusinessRole
      - BusinessCollaboration
      - BusinessPartner
        - Client
        - Consultant
        - Consumer
        - Contractor
        - ContractPartner
        - Customer
        - Influencer
        - Supplier
      - Employee
        - ClerkRole
        - ExpertRole
        - ManagerRole
    - CommunicationPath
    - InfrastructureElement
  - Interface
  - PassiveStructureElement
  - Service

APQC Proces<<<<<<s Framework

- owl:Thing
  - American Productivity and Quality Center
    - Acquire, Construct, and Manage Assets
    - Deliver Physical Products
      - Manage logistics and warehousing
      - Plan for and align supply chain resources
      - Procure materials and services
      - Produce/Manufacture/Deliver product
    - Deliver Services
    - Develop and Manage E
    - Develop and Manage H
    - Develop and Manage Products and Services
    - Develop Vision and Strategy
    - Manage Customer Service
    - Manage Enterprise Risk, Compliance, Remediation, and Resiliency
    - Manage External Relationships
    - Manage Financial Resources
      - Manage fixed-asset project accounting
      - Manage internal controls
        - Establish internal controls, policies, and procedures
        - Operate controls and monitor compliance with internal controls policies
        - Report on internal controls compliance
      - Manage international funds/consolidation
      - Manage taxes
      - Manage treasury operations
      - Perform general accounting and reporting
      - Perform global trade services
      - Perform planning and management accounting
      - Perform revenue accounting
      - Process accounts payable and expense reimbursements
      - Process payroll
    - Manage Information Technology (IT)
    - Market and Sell Products and Services

'Produce/Manufacture/Deliver product'
http://ikm-group.ch/archimeo/apqc#4_3_Produce_Manufac

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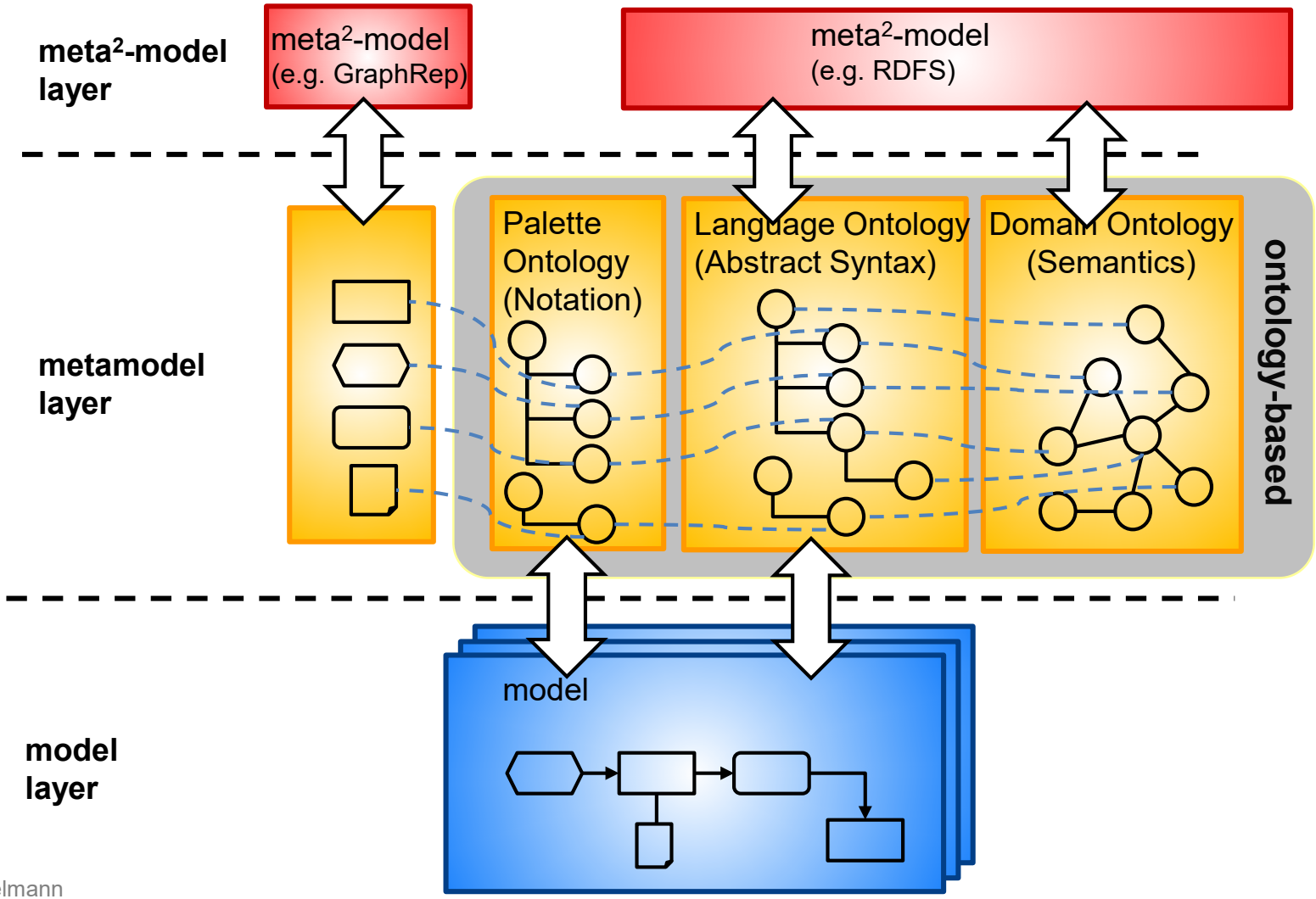
Ontology-based Metamodeling (3): Ontologies for Language, Metamodel and Content



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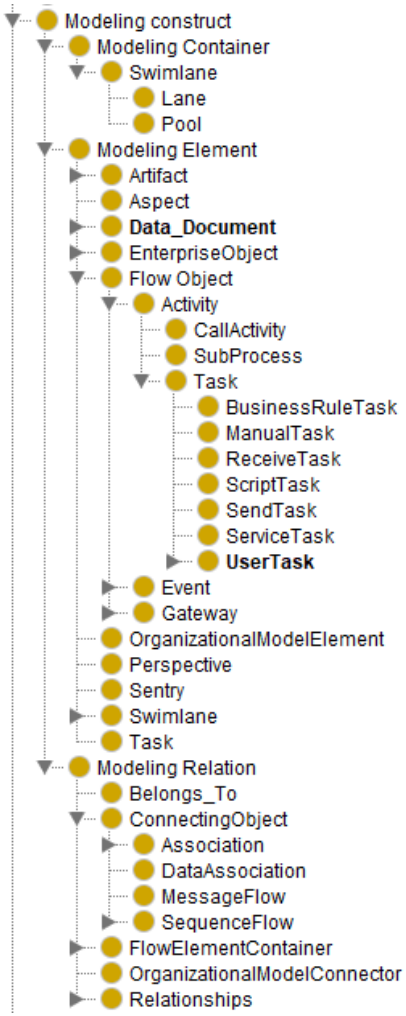
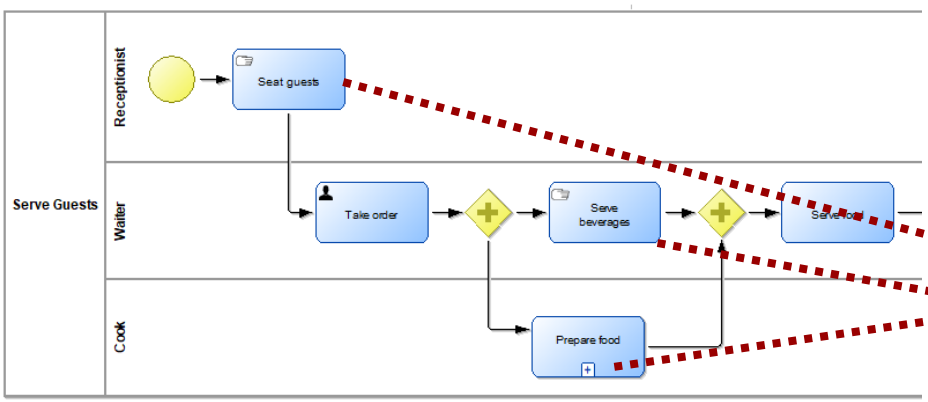
Palette Ontology

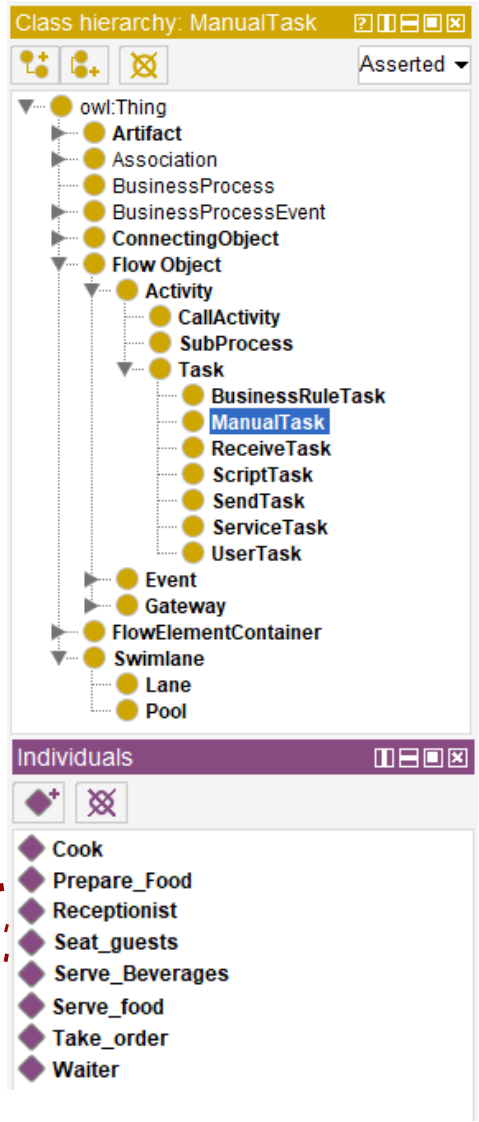
Palette Ontology (excerpt9



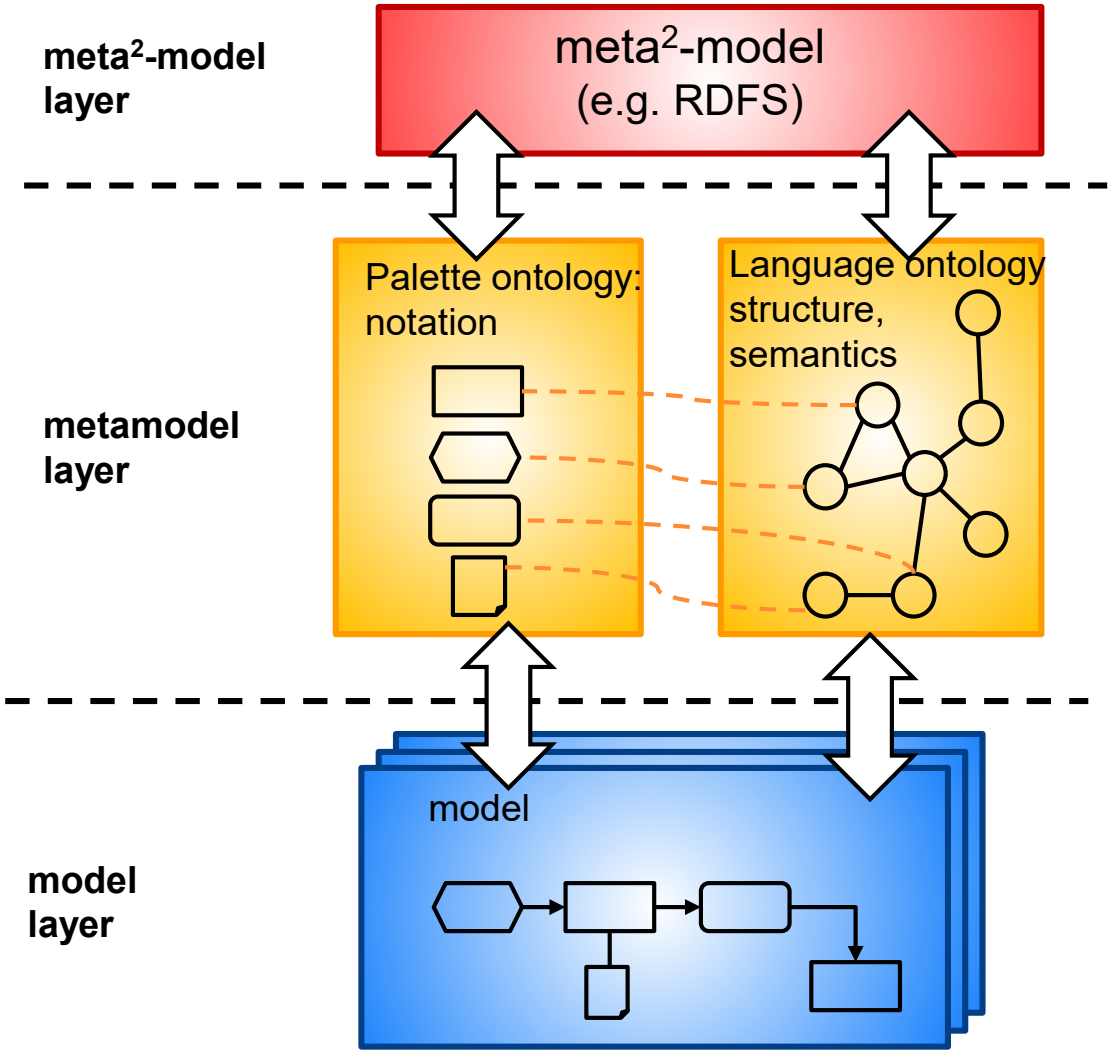
Ontology-Based Metamodel

- Single environment for modelling and ontology
- Model elements are directly created as instances in the ontology





Ontology-based Metamodeling: Metamodel is represented as an Ontology



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Agile Modelling

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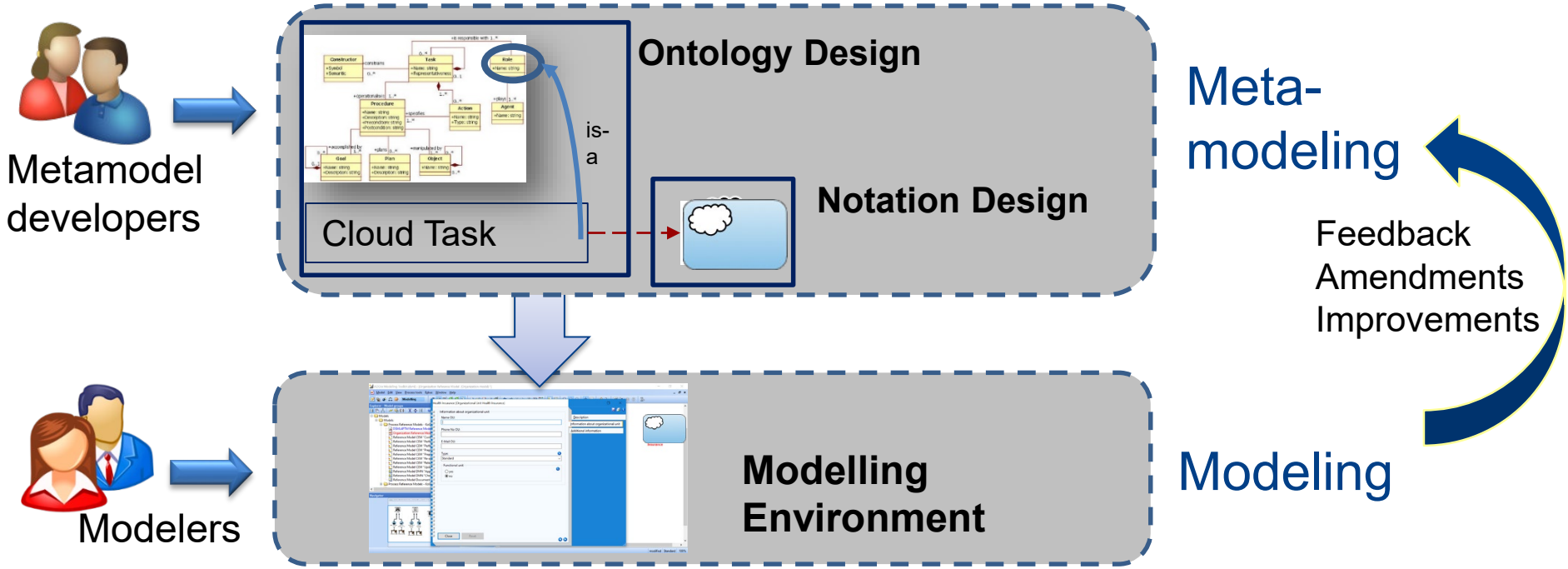
Objective

Ensure a precise shared interpretation of new modeling constructs to both **humans and machines**

Problem: Separation between Metamodel Developer and Modeler

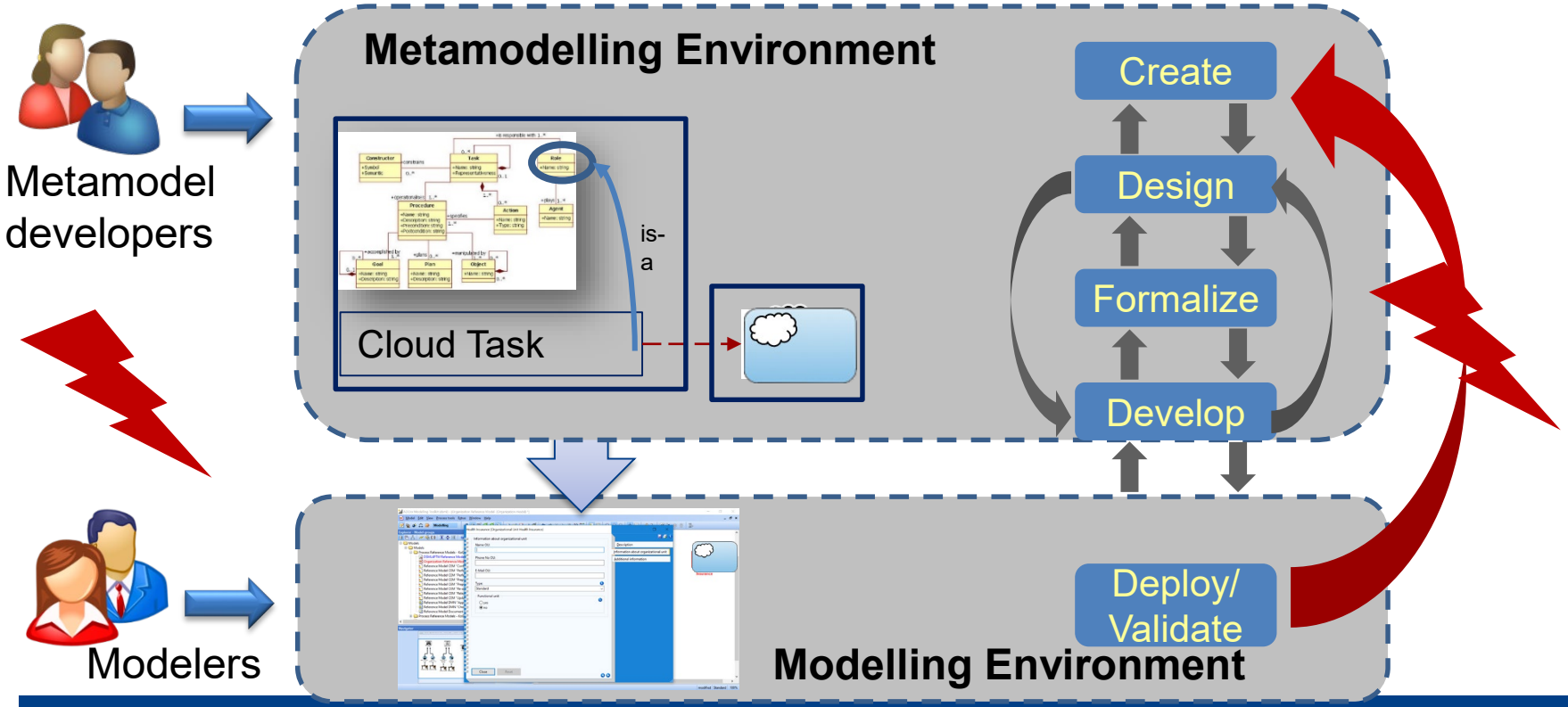


Challenge: Separation of metamodelling and modelling
(typically in separate environments, e.g. ADOxx Development and ADOxx Modelling Toolkits)

Objective: Integrate metamodeling and modeling in a single environment

Thanks to Emanuele Laurenzi

Problem: Separation between Metamodel Developer and Modeler



Challenge: Separation of the metamodelling and metamodelling
(typically in separate environments, e.g. ADOxx Development and ADOxx Modelling Toolkits)

Objective: Integrate metamodeling and modeling in a single environment

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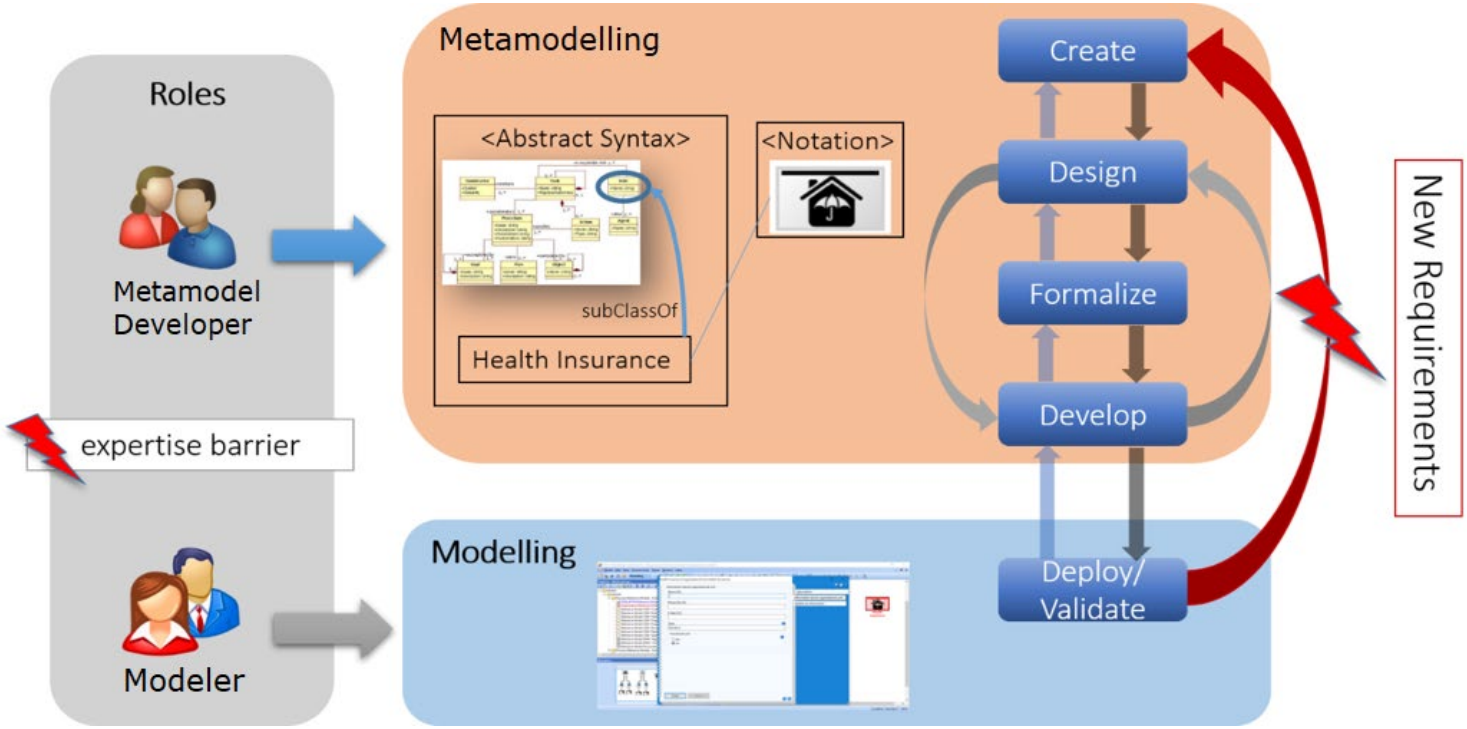
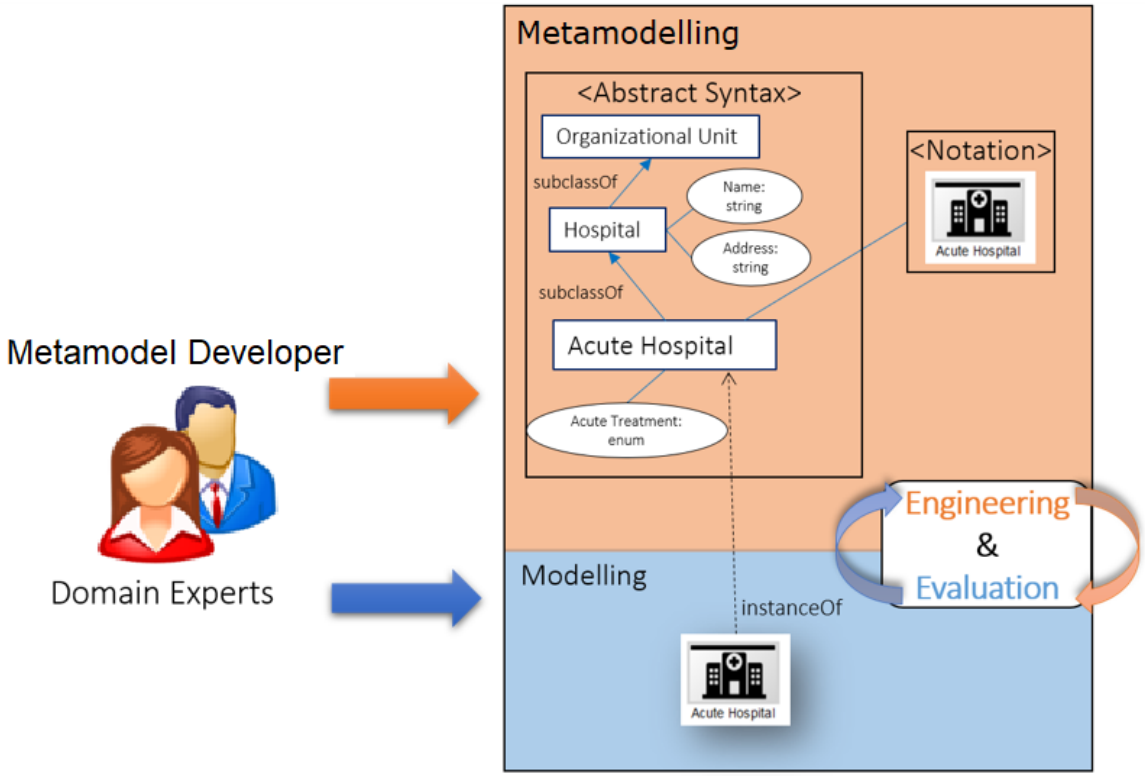
Challenge: Separation of metamodelling and modelling



- Challenge 1: Metamodeling is a joint effort between metamodel experts and domain experts
- Challenge 2: Sequentialization of metamodeling and modeling is time consuming

Integration Modeling and Metamodeling in a Single Environment

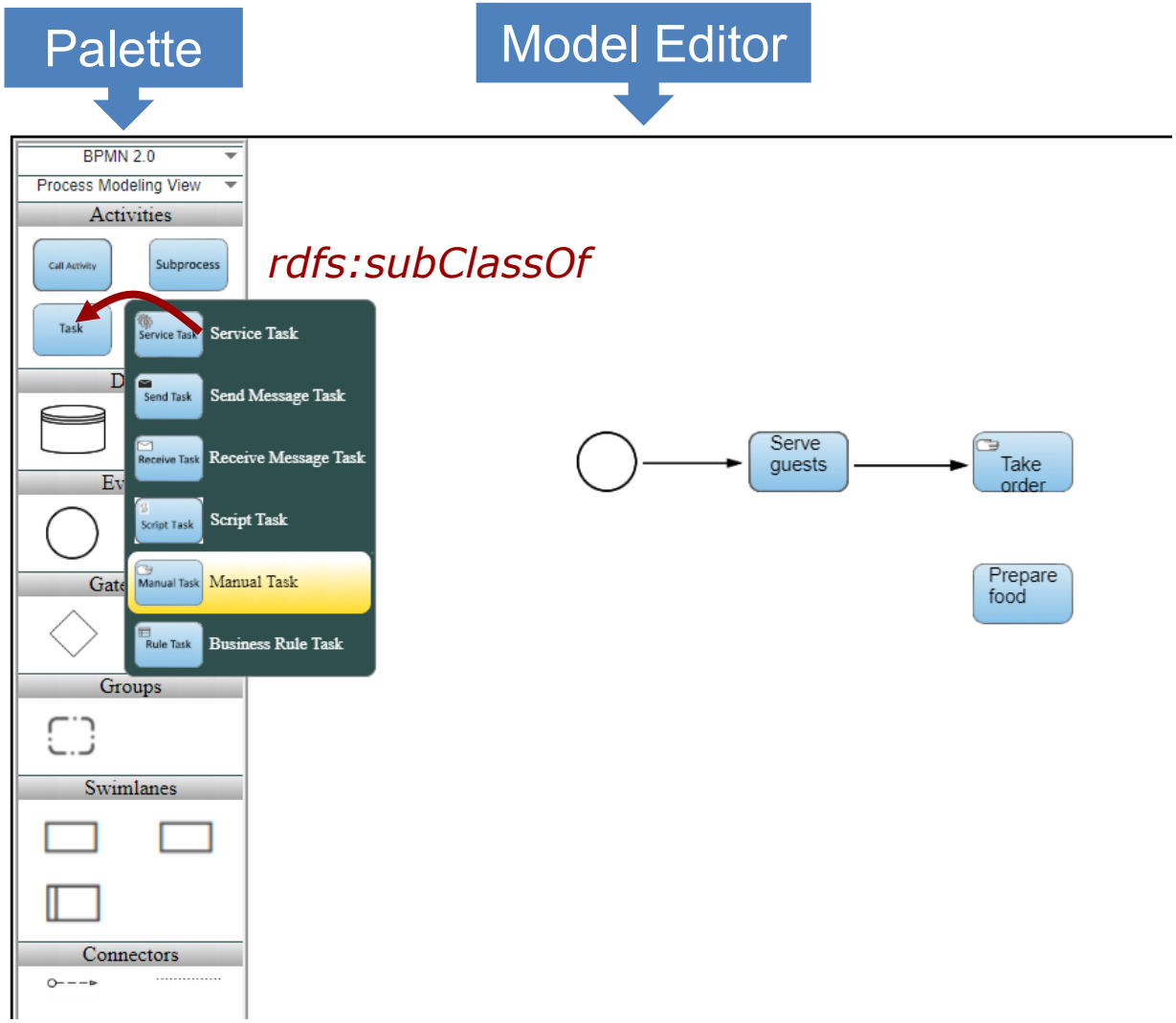
- Tight collaboration between metamodel developer and modeler
- Modeler can also take the role of metamodel developer



AOAME: Agile and Ontology-Aided Modeling Environment

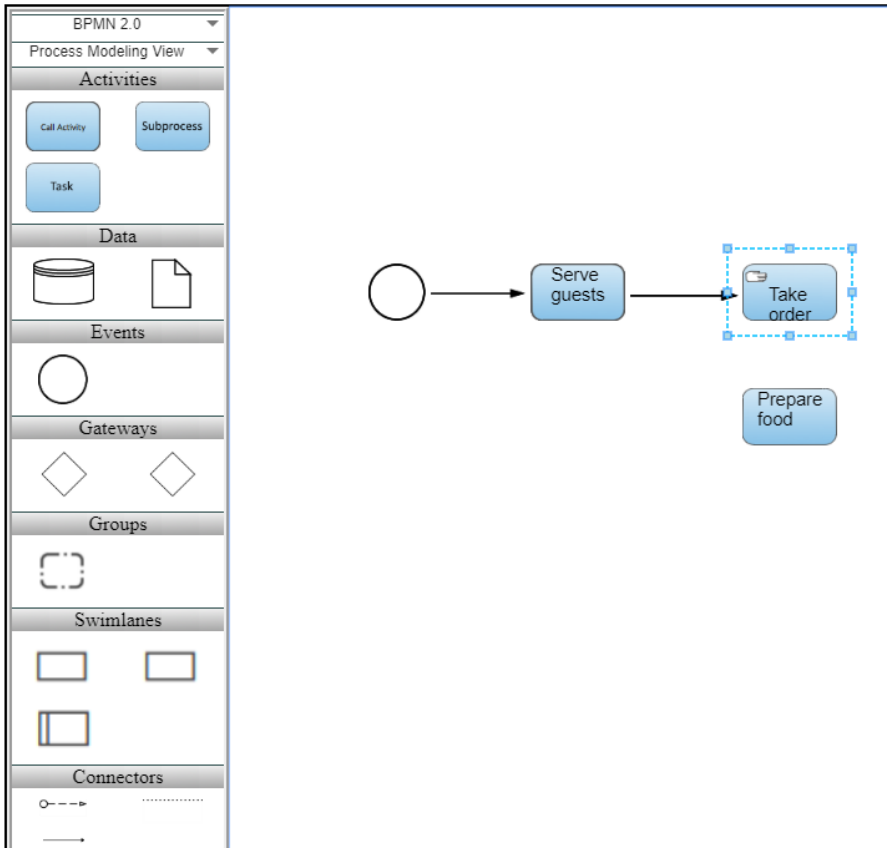
- AOAME is a a prototypical implementation for Agile and Ontology-Aided Modeling
- It is based on the PhD Thesis of Emanuele Laurenzi
- Implementation of the current version by
  - Emanuele Laurenzi
  - Charuta Pande
  - Devid Montecchiari

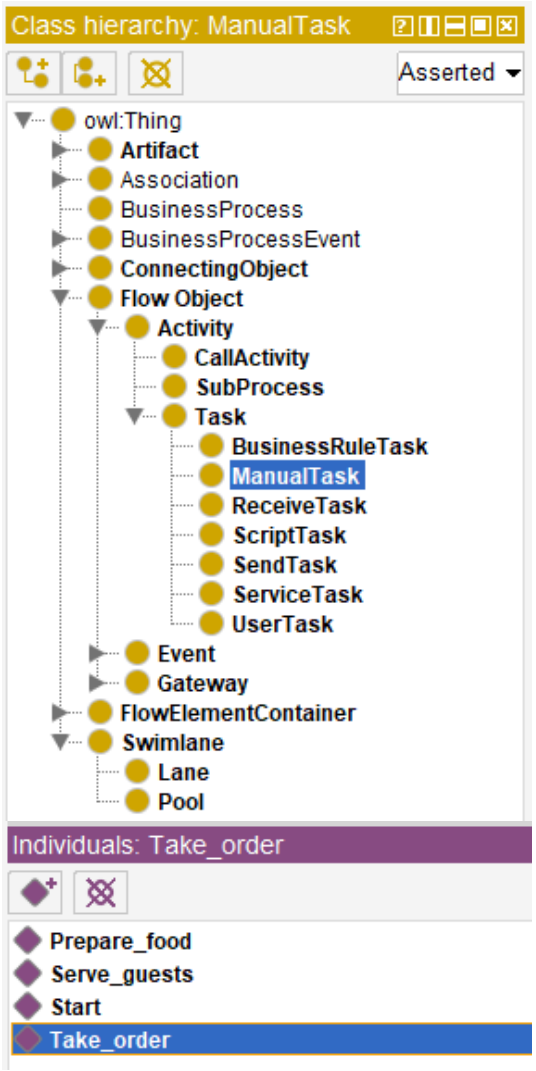
Ontology-Based Modeling in AOAME



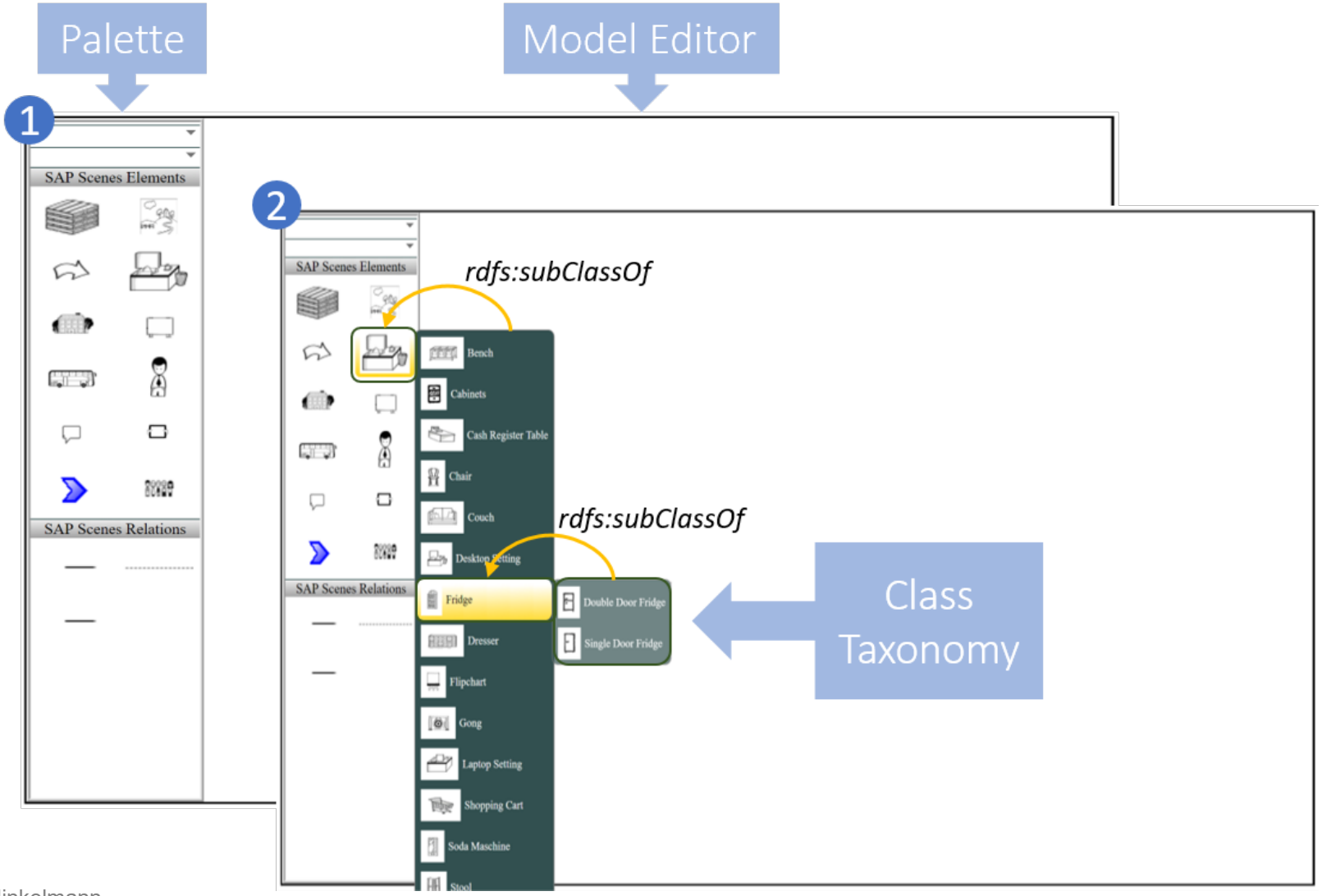
Ontology-Based Modelling

Model elements are directly created as instances in the ontology
Modelling and ontology in a single environment

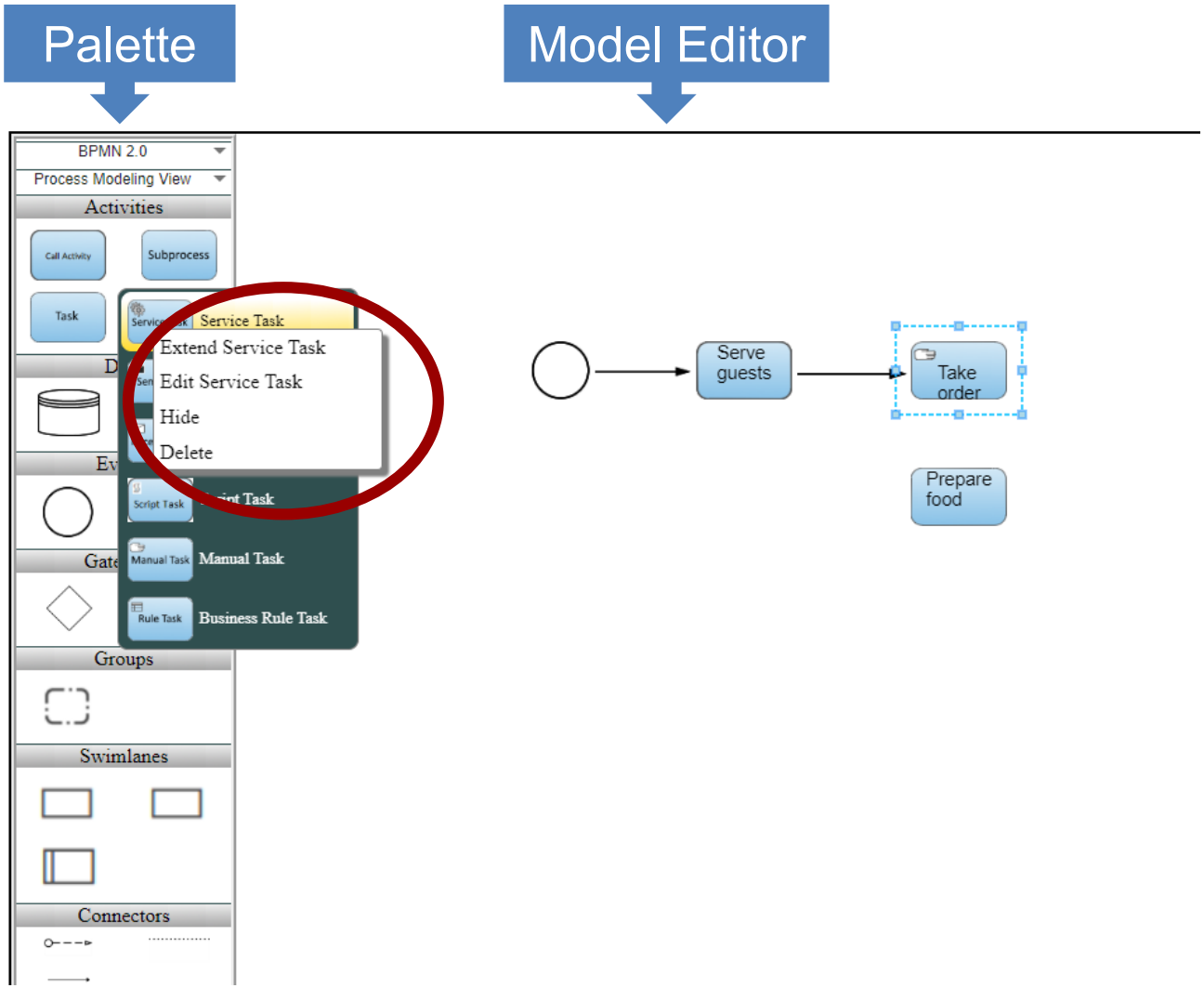




Modeling Elements are represented in a Class Hierarchy



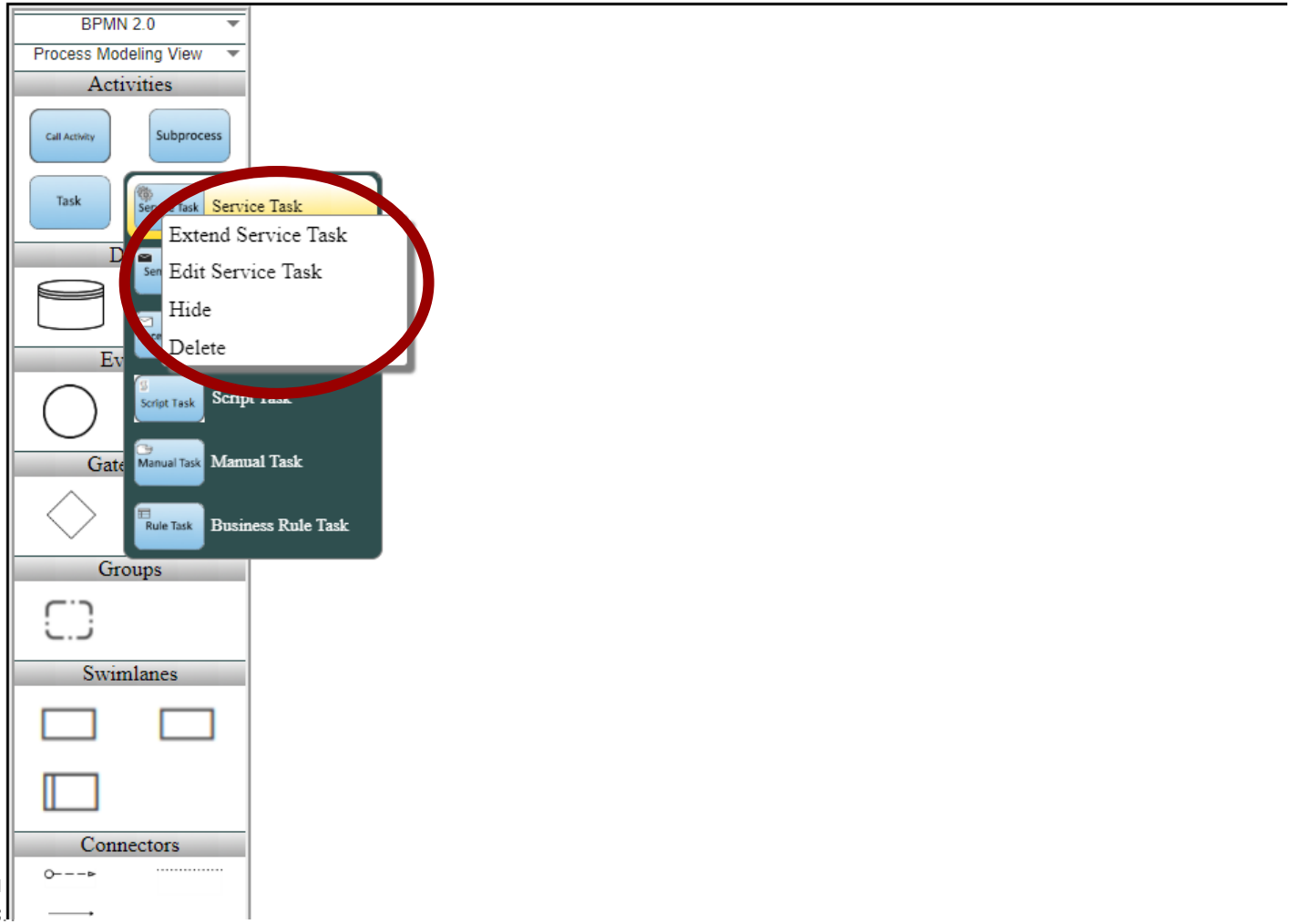
Extending AOAME Modeling Languages – on the fly



Extending AOAME Modeling Languages

Palette

Model Editor



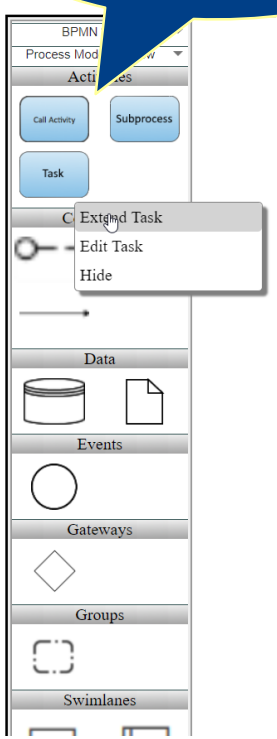
Integration of Meta-modeling and Modeling: On-the-fly Modeling Language Adaptation

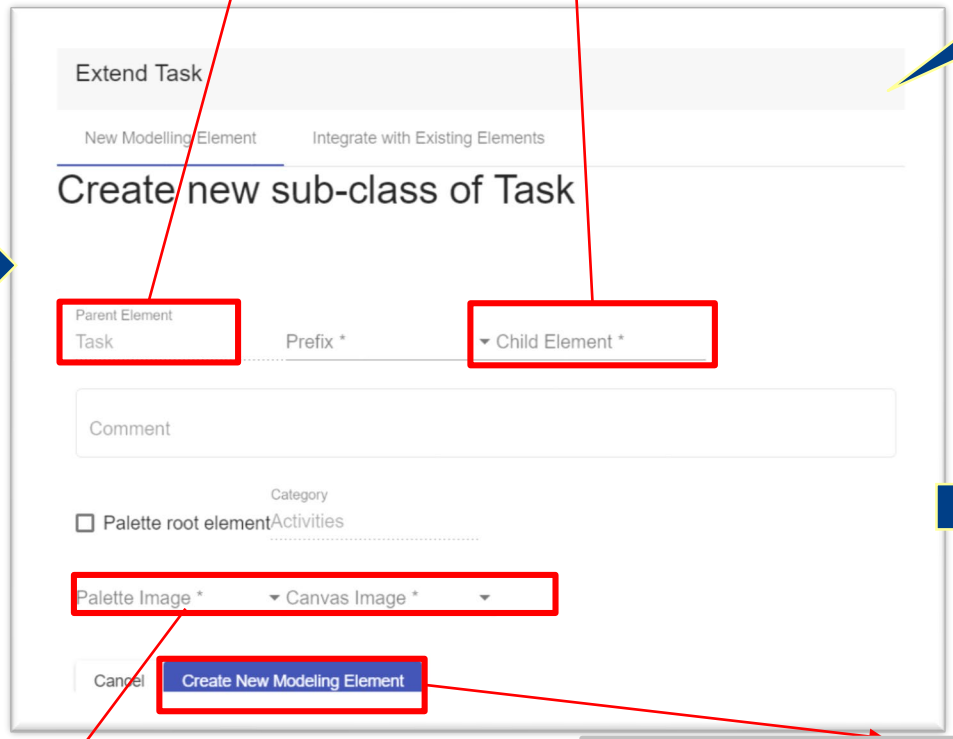
Ontology-based palette

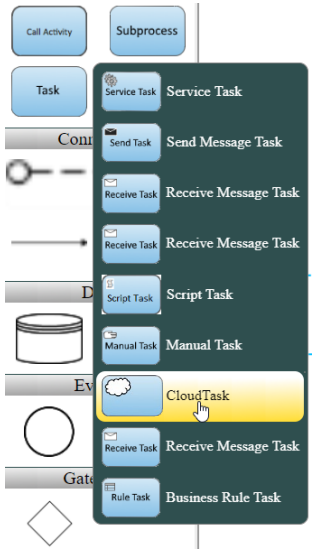
Ontology-based metamodel

Name of the parent class

Name for the new modeling construct







Graphical notation to be shown in palette and canvas

Create New Modeling construct and store in the ontology

Thanks to Emanuele Laurenzi

Hands-on Agile and Ontology-Aided Modeling in AOAME

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