

Towards a Unified Assembly System Design Ontology using Protégé

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Aim and Structure

Develop a Unified Ontology that will enable seamless Collaboration and use of Top-of-its-Class tools within the area of Assembly System Design.

- ❑ Motivation
- ❑ Related Projects
- ❑ Methodology Overview
- ❑ Knowledge Representation Approach
- ❑ Assembly System Design Ontology
- ❑ Application Example
- ❑ Conclusions and Future Work

Motivation

□ Challenges:

- Shorter Product Lifecycles
- Increasing Product Complexity
- Assembly forms 80% of a Products Manufacturing Cost

□ Enabling Factors:

- Rapid Design and Manufacturing on Demand
- Integration of all Stakeholders in the Decision Making Process
- Unified Assembly Domain Ontology

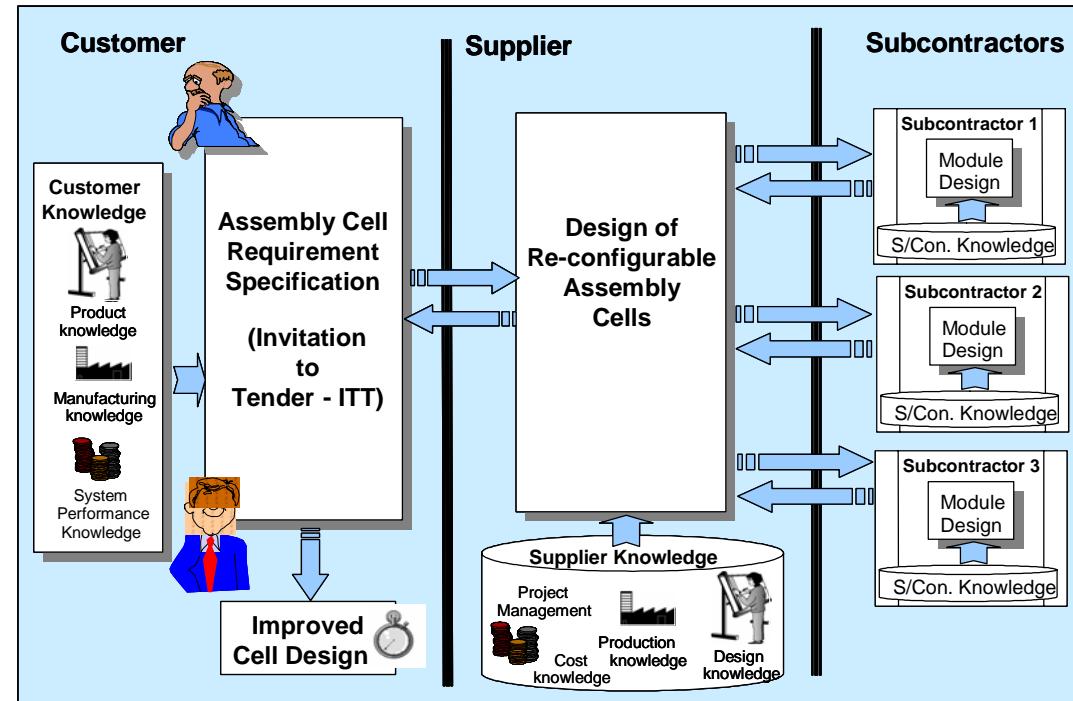
Related Projects

AIM

E-RACE aims to develop a collaborative design e-space consisting of integrated methods, tools, knowledge representation models and training materials to support the distributed requirement capture and conceptual design process for manufacture of reconfigurable assembly cells.

KEY INNOVATIONS

- A **virtual design space** to allow large end users and SME suppliers to collaborate in developing production automation and test systems.
- Overall improvement in equipment specification and response time leading to improved competitiveness of the users and manufacturers involved



CURRENT PARTNERS

UK - TQC Ltd (coordinator), **University of Nottingham**, Southco, Glaxo Smith Kline , British Automation and Robotics Association

Finland – TUT, VTT, Visual Components

Portugal – **Universidade Nova**, Flexcomp

Sweden – KTH, FlexLink

Switzerland – EPFL, Mikron

EUPASS

Evolvable Ultra-Precision Assembly Systems

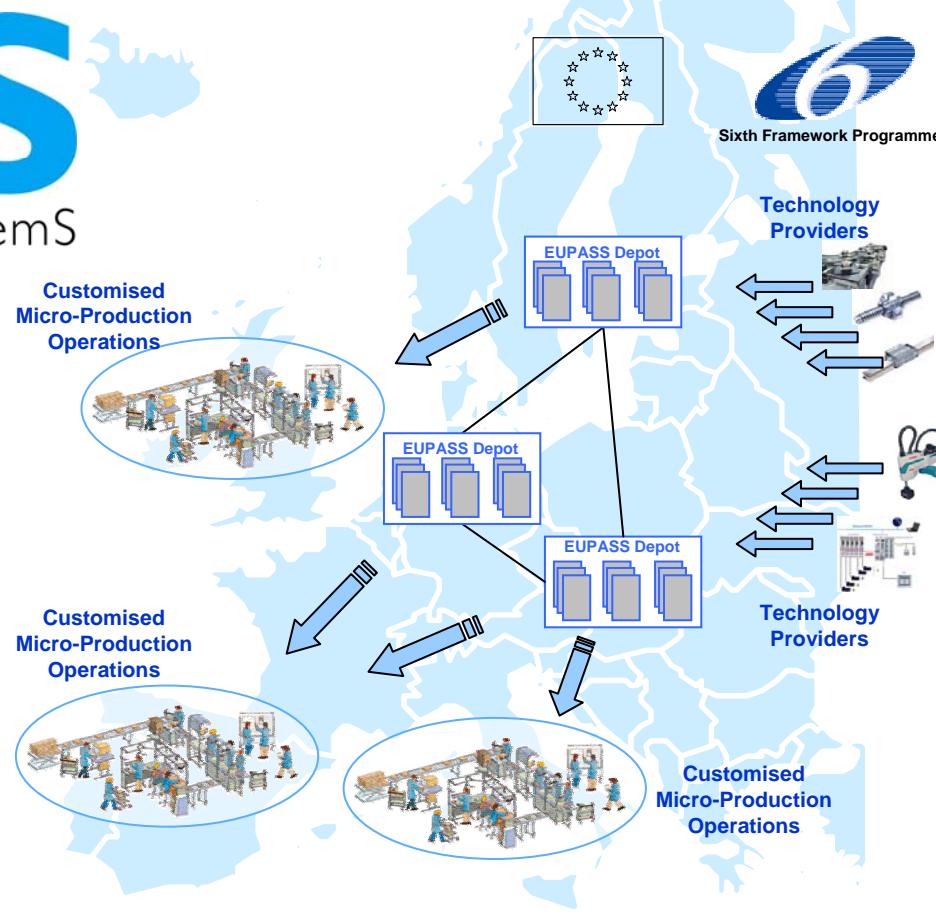


Sixth Framework Programme

MISSION STATEMENT

The EUPASS consortium has a mission to facilitate the development, implementation and promotion of affordable, cost effective and sustainable ultra-precision manufacturing solutions by offering rapidly deployable ultra-precision assembly services on demand. This will be achieved by developing and delivering a number of breakthrough technologies and solutions including:

- European wide **pilot infrastructure** of micro-assembly module depots and integration software
- Robust and legacy-compliant knowledge driven **methodology, cost models** and **software tools**
- Next **generation ultra-precision enabling technologies** for the realisation of a high-precision assembly cell



PARTICIPANTS

Netherlands - Philips

Germany - Bosch, Festo, Beckhoff, IEF Werner, FZ Karlsruhe

Italy - Electrolux, Masmec, ITIA

Sweden - FlexLink, KTH

Switzerland - Feintool Automation AG, FHS Solothurn, EPFL

France - UFC/Besançon

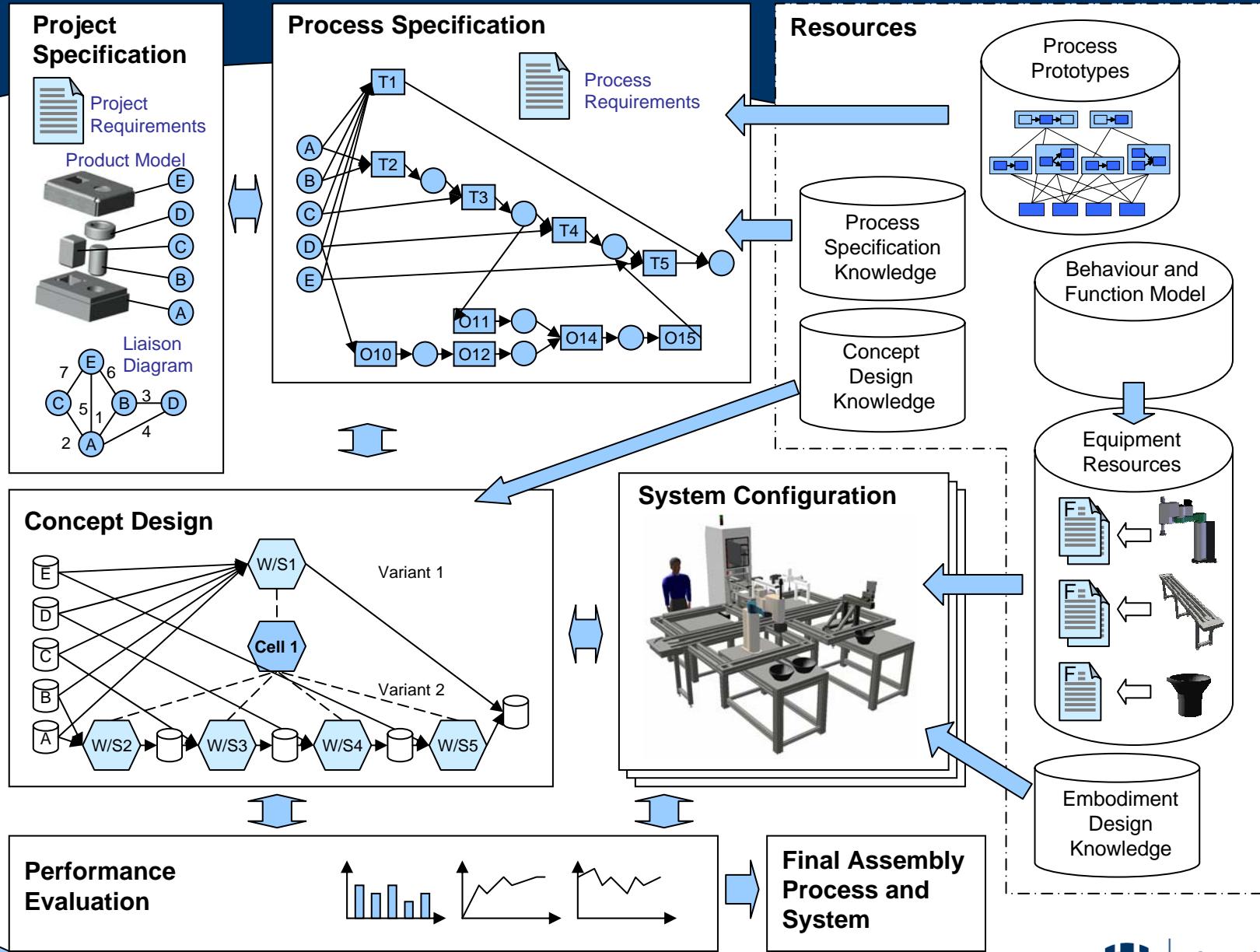
UK - TQC, University of Nottingham

Portugal - Universidade Nova

Finland - TUT

Methodology Overview

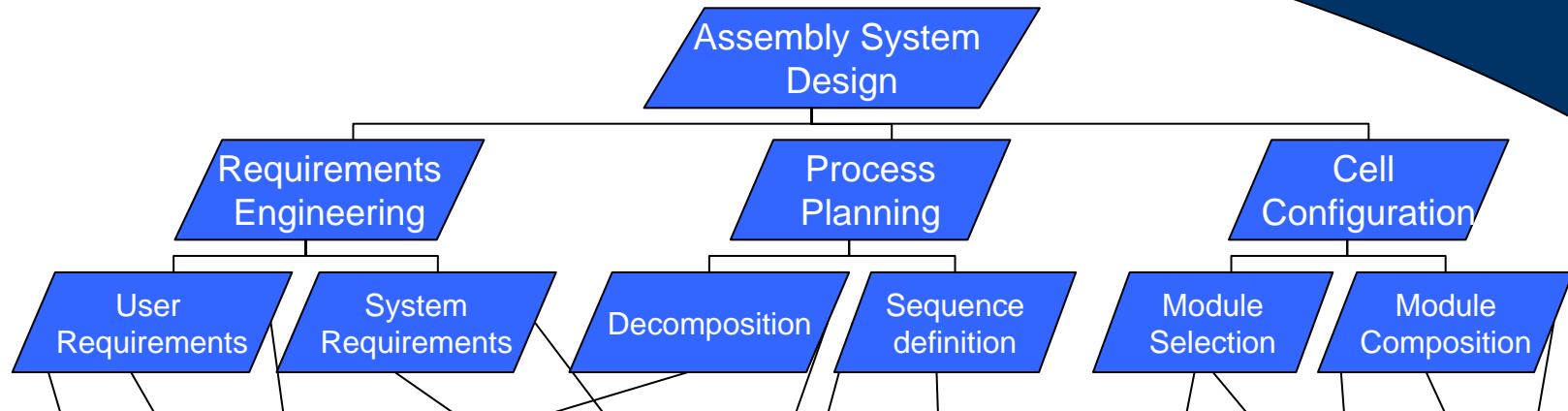
Assembly System Reconfiguration Methodology



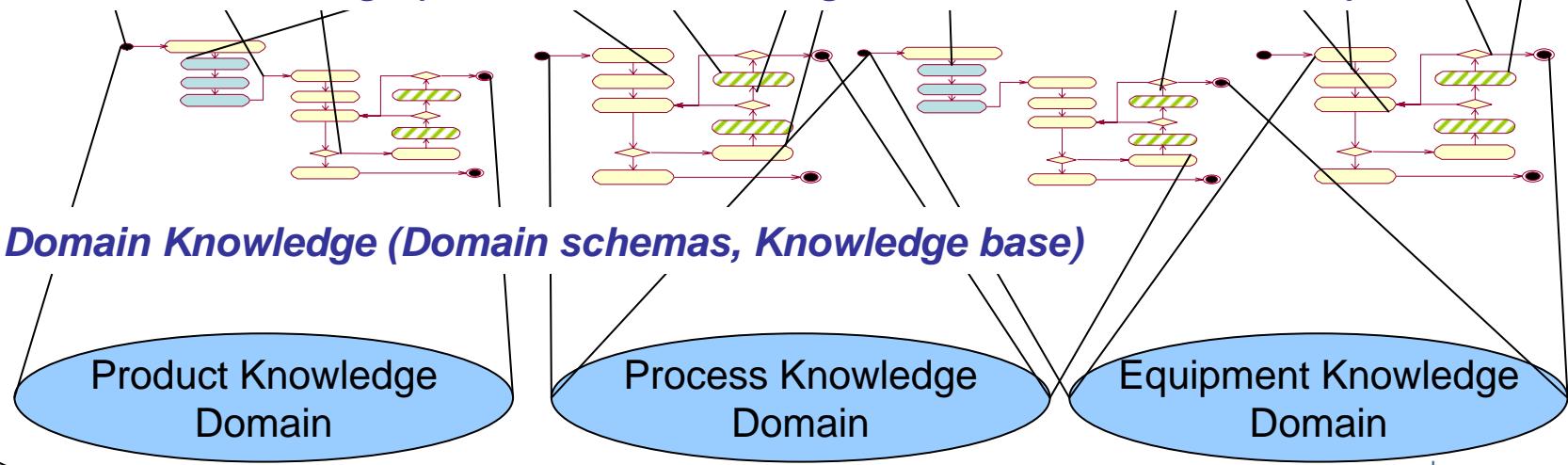
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N. Lohse et al., Protégé2005, Madrid, Spain, 18-21 July 2005

CommonKADS Framework

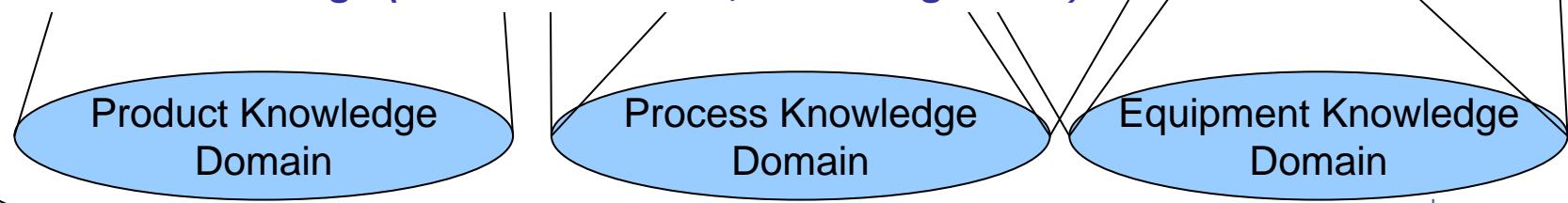
Task Knowledge (Tasks, Goals, Task Methods)



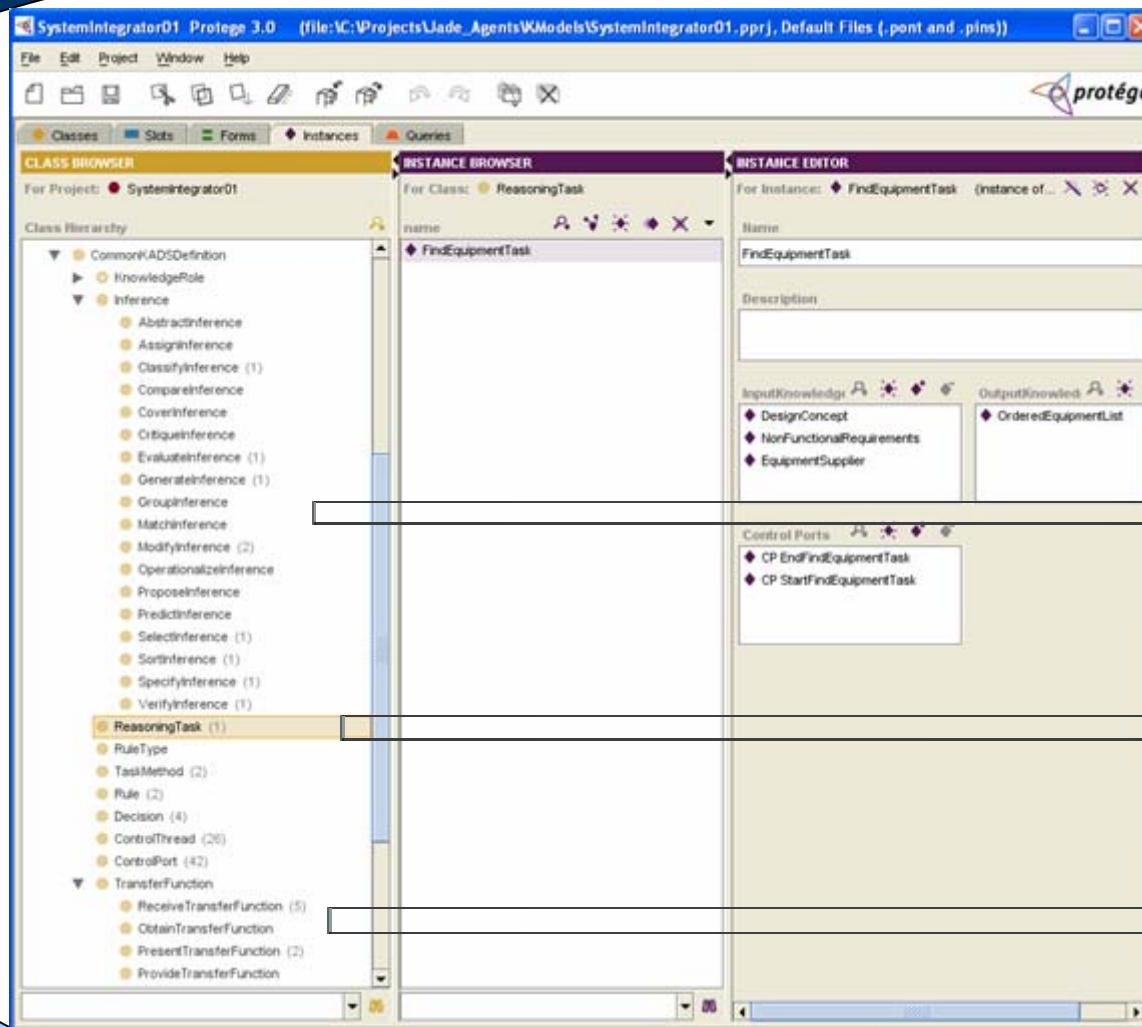
Inference Knowledge (Inferences, Knowledge roles, Transfer functions)



Domain Knowledge (Domain schemas, Knowledge base)



Decision Making Model



Inference Structure

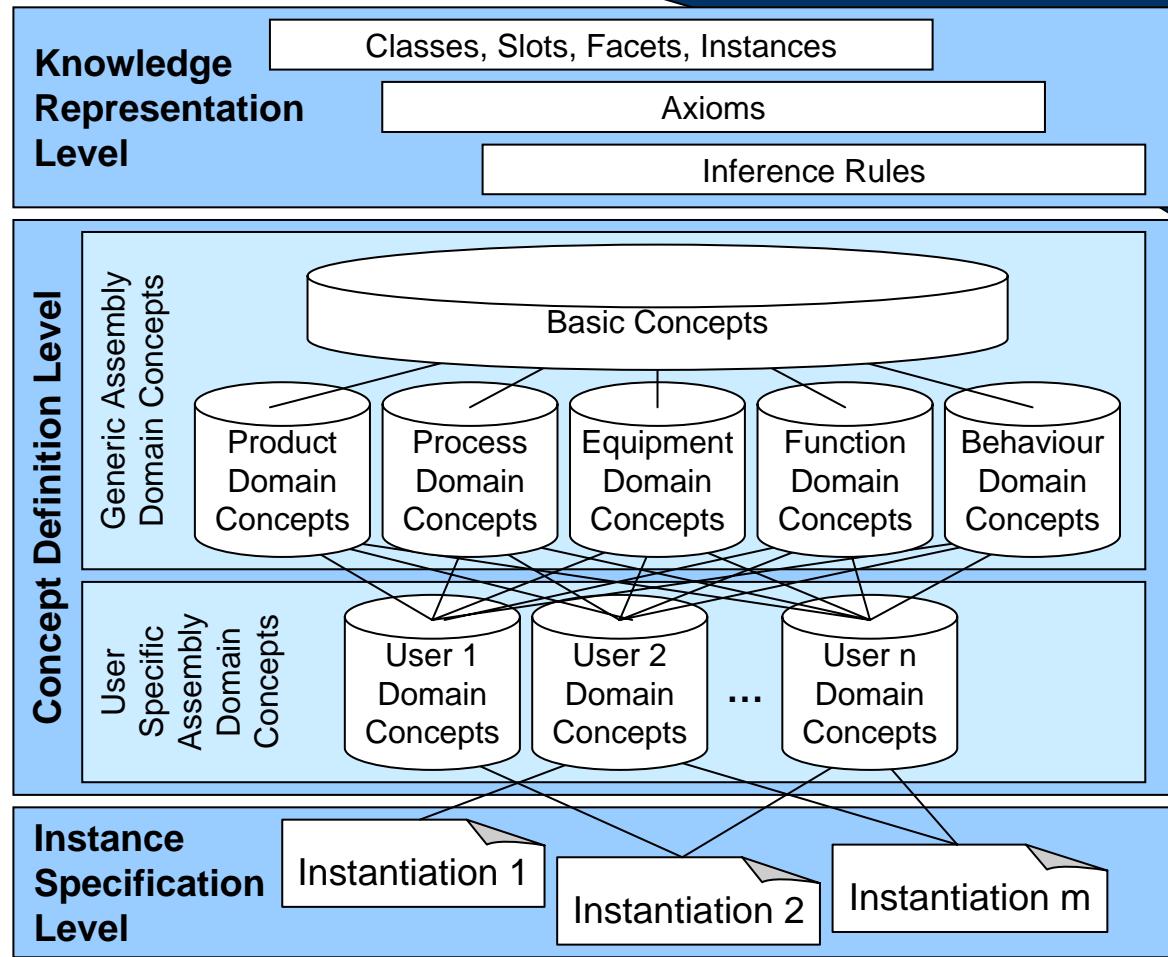
Reasoning Task

Transfer Functions

Ontology Structure

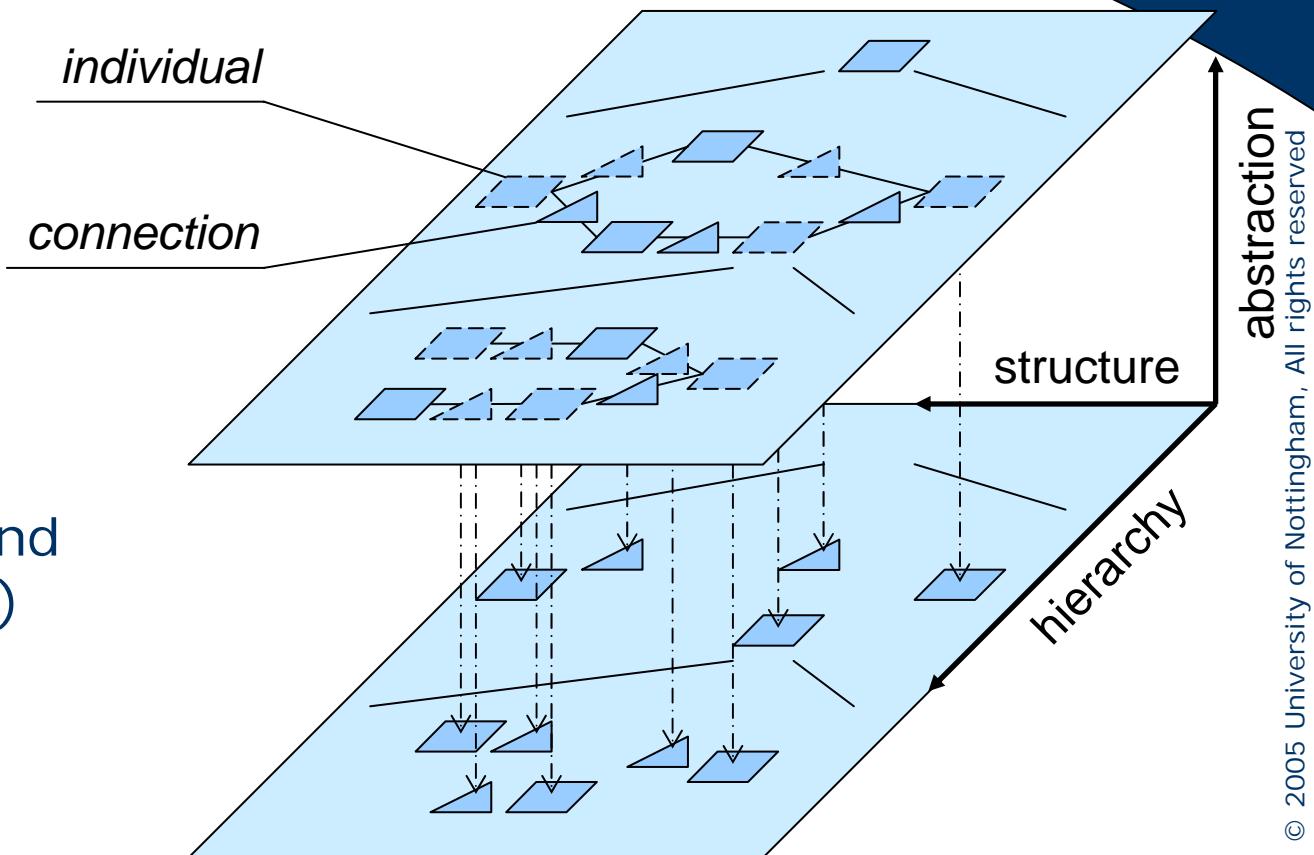
Ontology Structure

- Extendable
- Traceable
- Abstraction
 - Incomplete Definitions
- Multi Disciplinary
- Exchangeable
- Human Readable
- Computer Interpretable
- Information Redundancy



Basic Concept Structure

- Mereology
 - Defines the hierarchy
- Topology
 - Defines the structure
- Taxonomy
 - Defines the classification
(abstraction and generalisation)

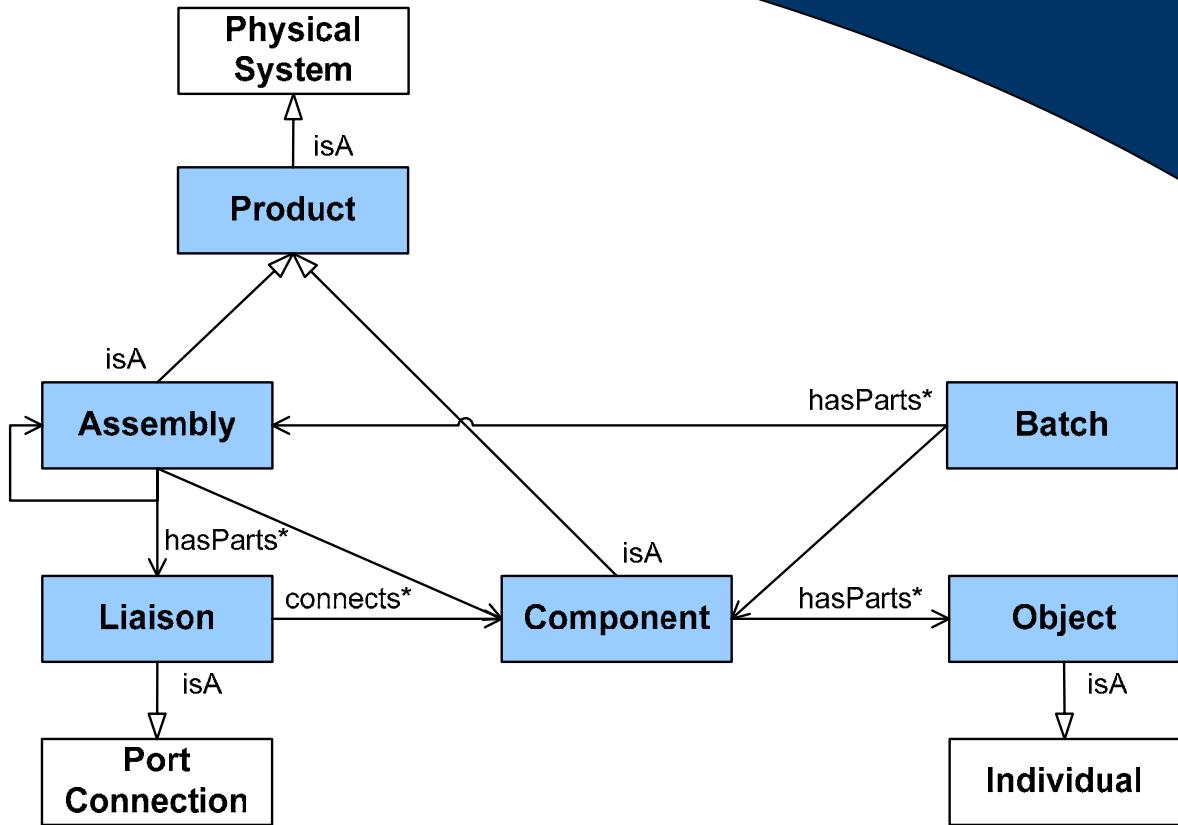


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Domain Concept Models

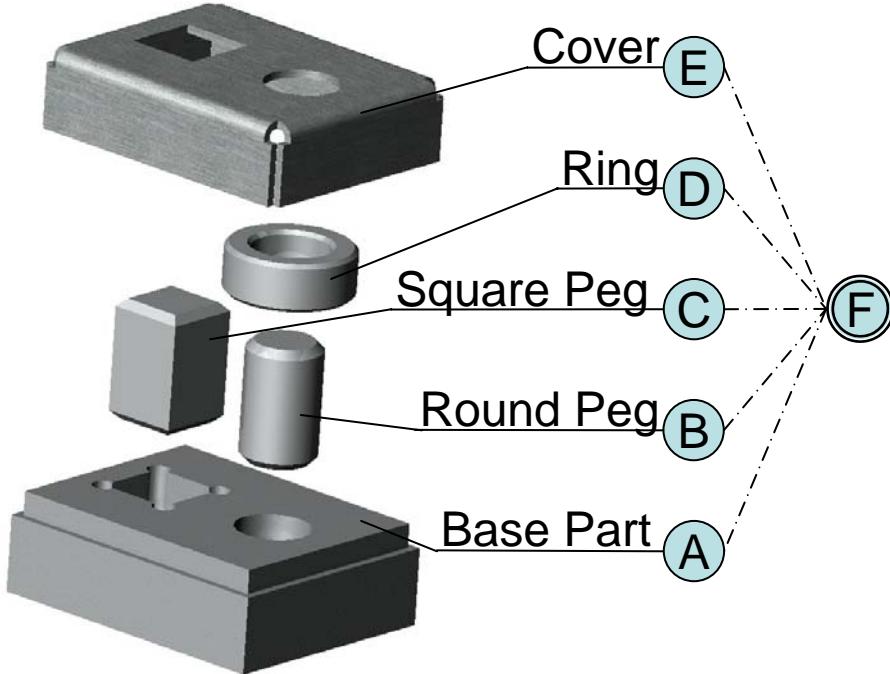
Product Domain Concepts

- Spatial Structure
- Logical Structure
 - Hierarchy
 - Liaisons
- Assembly Characteristics
- Process History
- Design Status

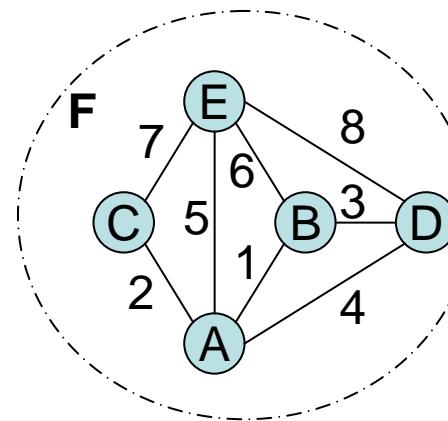


Example: Simple Assembly

□ Logical Structure

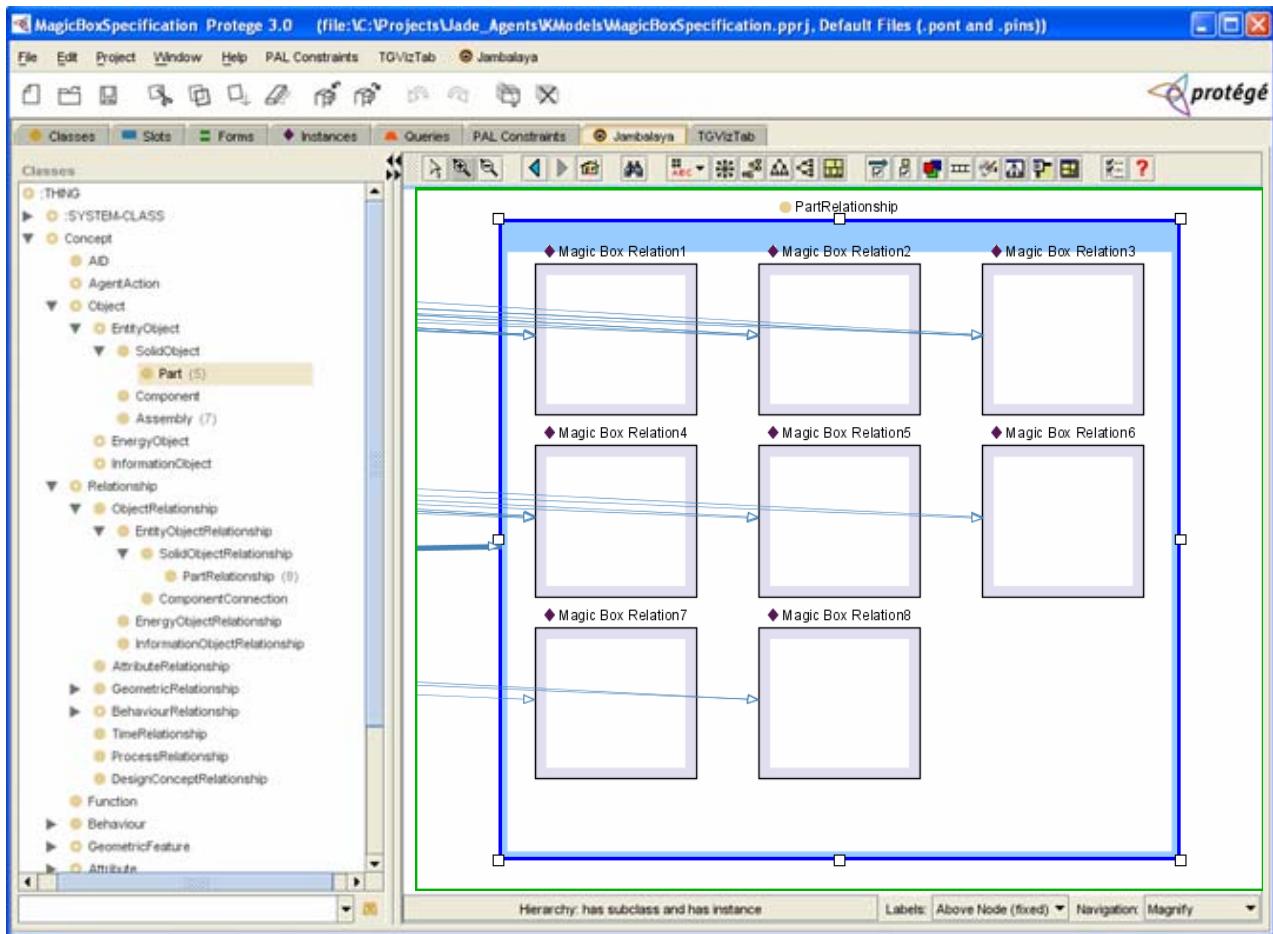


□ Spatial Structure



- 1 = <LooseFit> and contact between A and B
- 2 = <LooseFit> and contact between A and C
- 3 = <LooseFit> between B and D
- 4 = <Contact> between A and D
- 5 = <TightFit> and contact between E and A
- 6 = <LooseFit> between E and B
- 7 = <LooseFit> between E and C
- 8 = <Contact> between E and D

Product Domain Concept



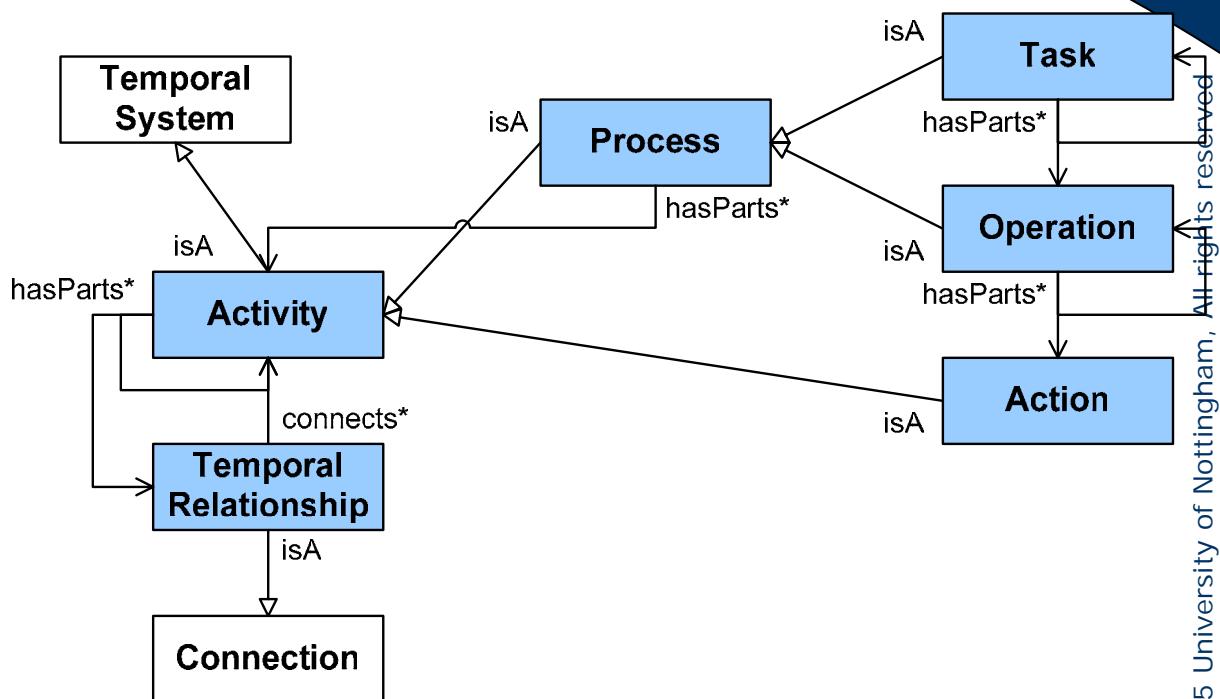
Assembly Process Domain Concepts

□ Temporal Structure

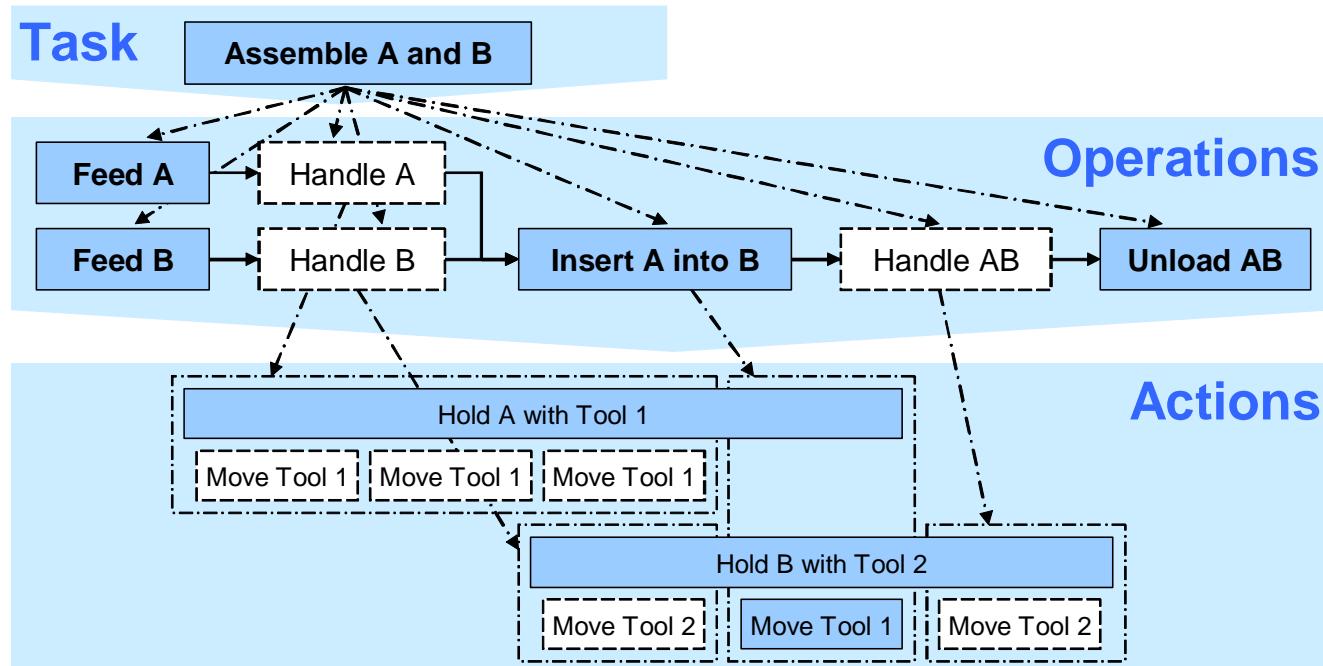
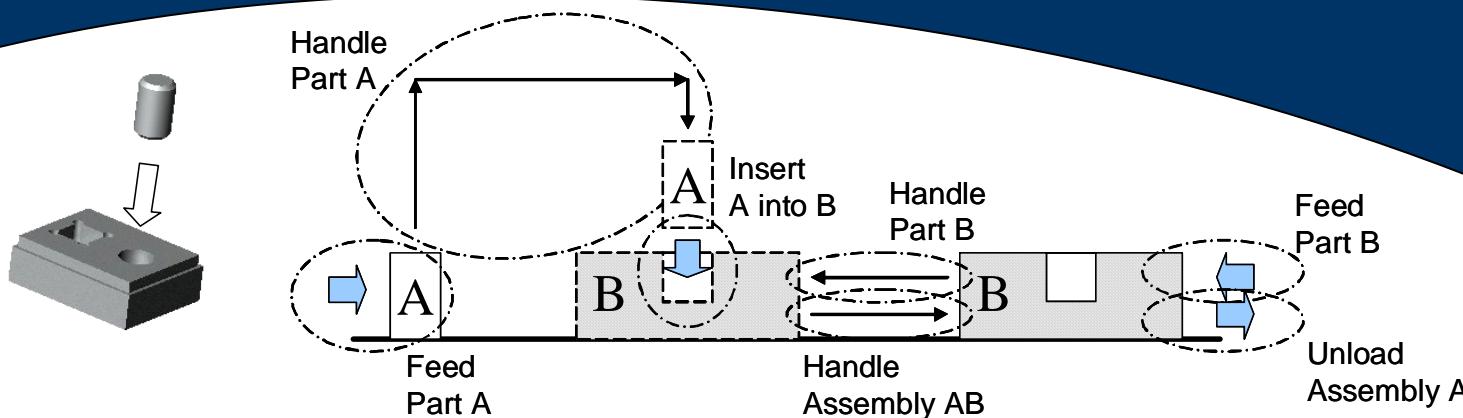
- Sequences
- Parallelism
- Loops

□ Logical Structure

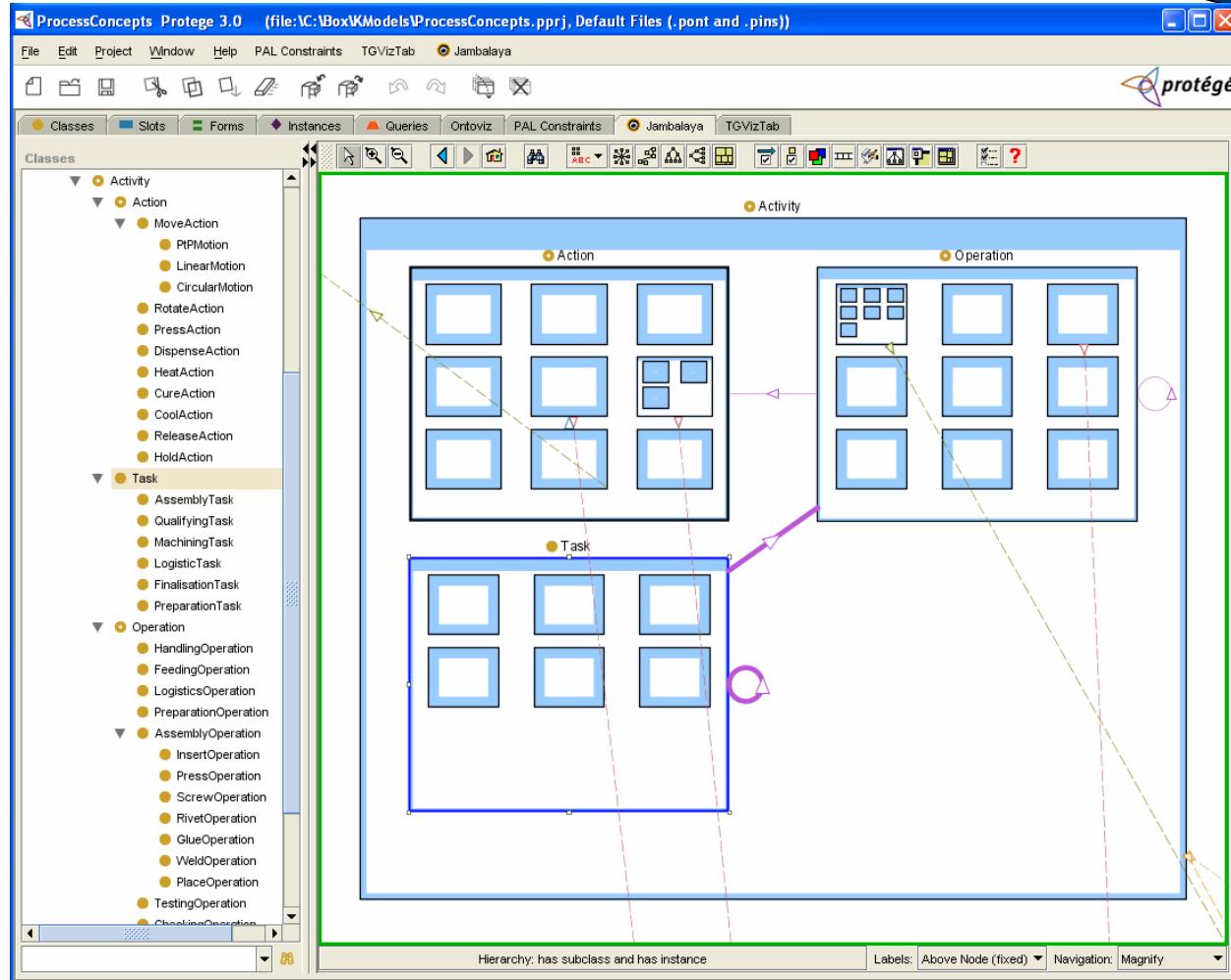
- Hierarchy
- Alternative Decompositions



Example: Insertion Task Breakdown

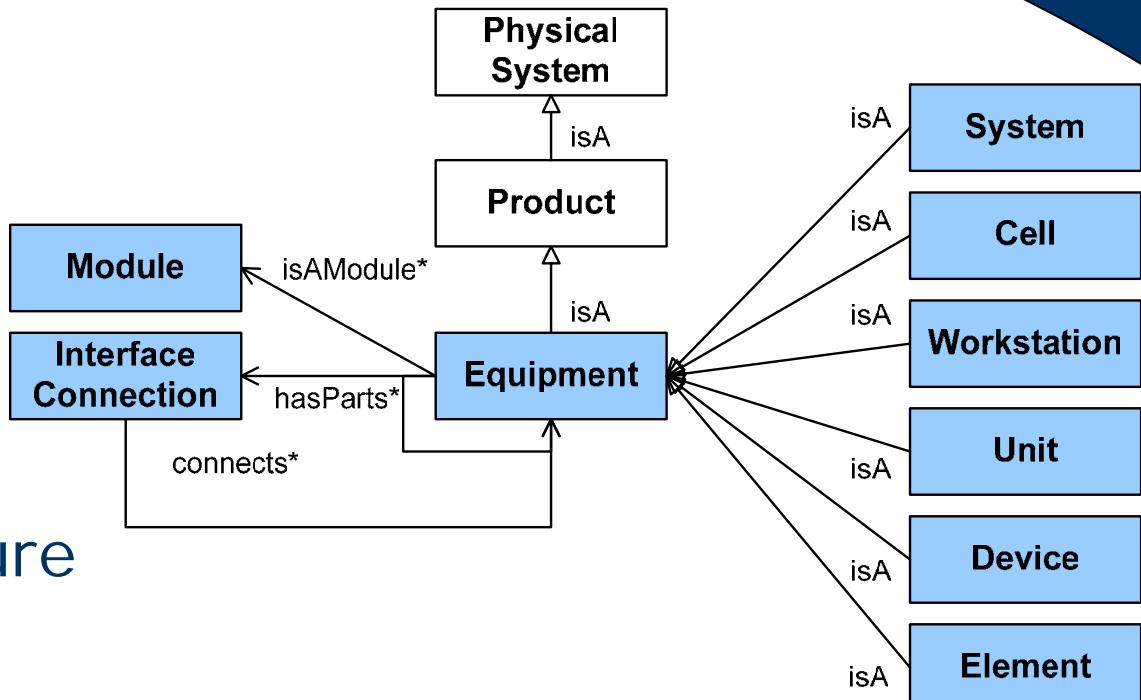


Process Domain Concept

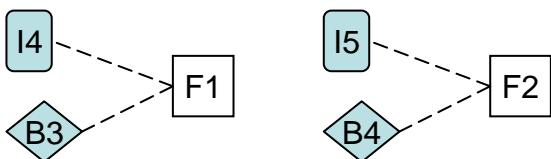
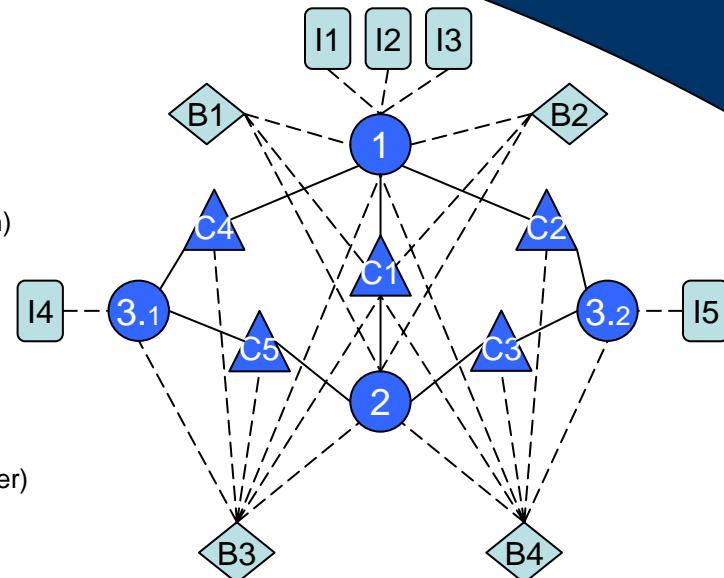
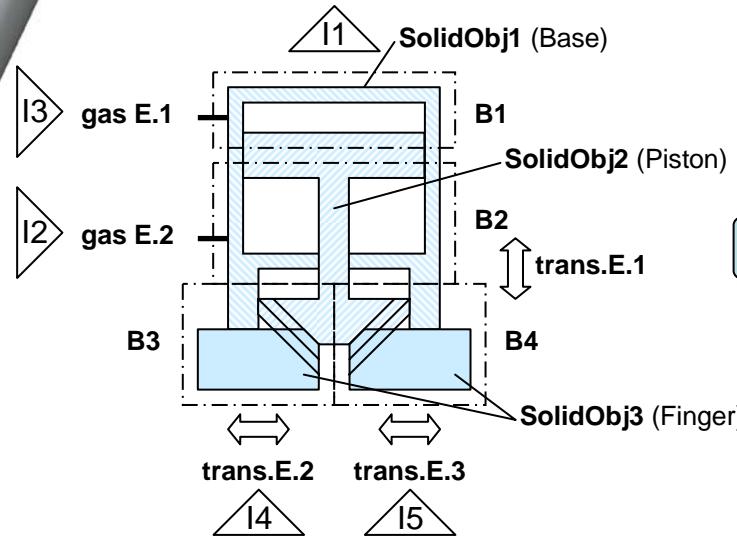
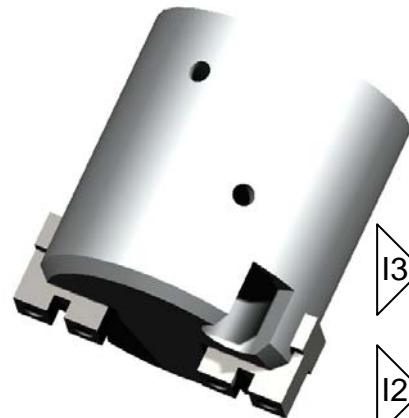


Assembly System Domain Concepts

- Spatial Structure
- Logical Structure
 - Hierarchy
 - Connectivity
 - Constraints
- Behavioural Structure
 - Performance Characteristics
- Functional Structure
 - Capabilities
- Costing Information
- Delivery Times



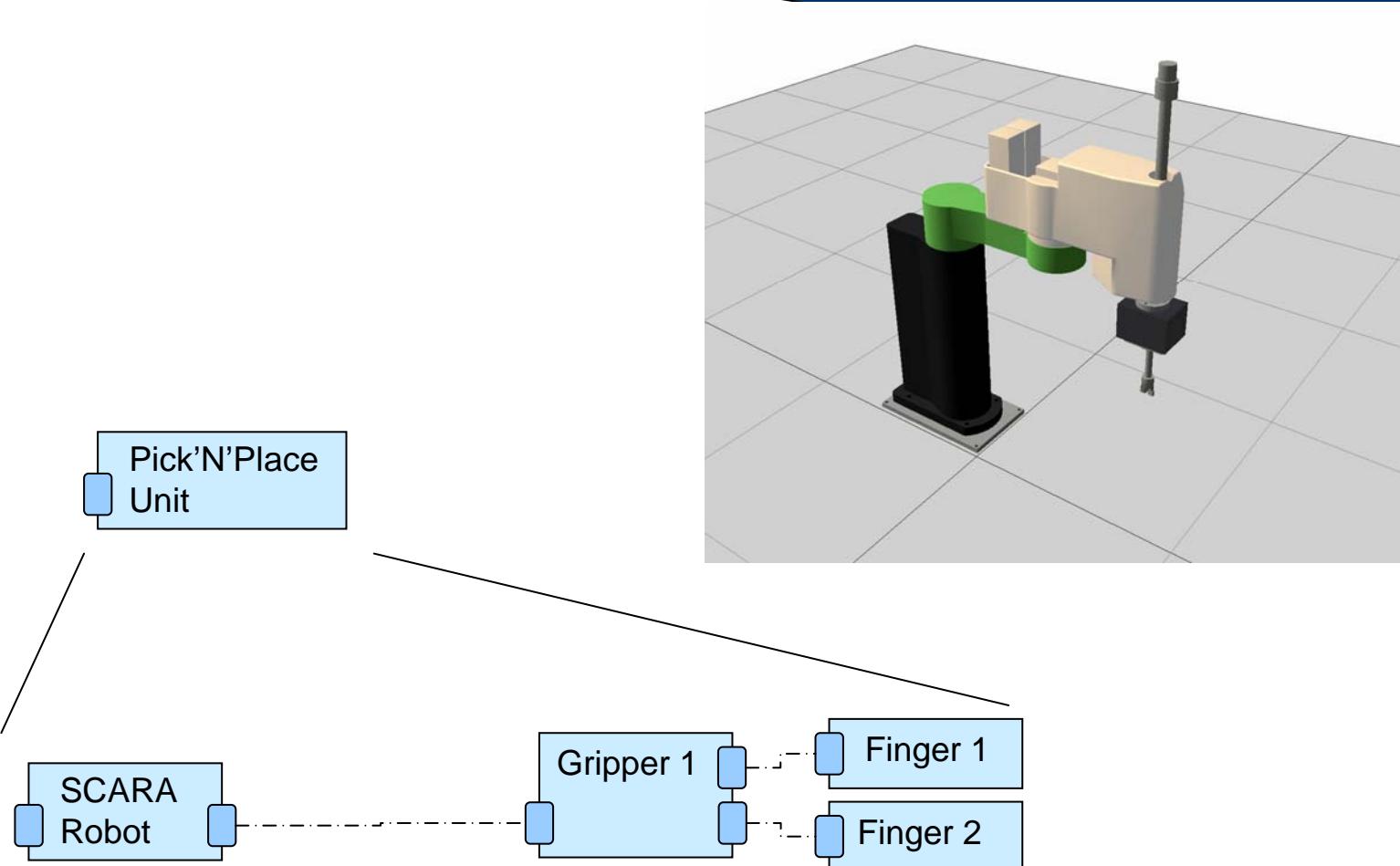
Example: Equipment Device



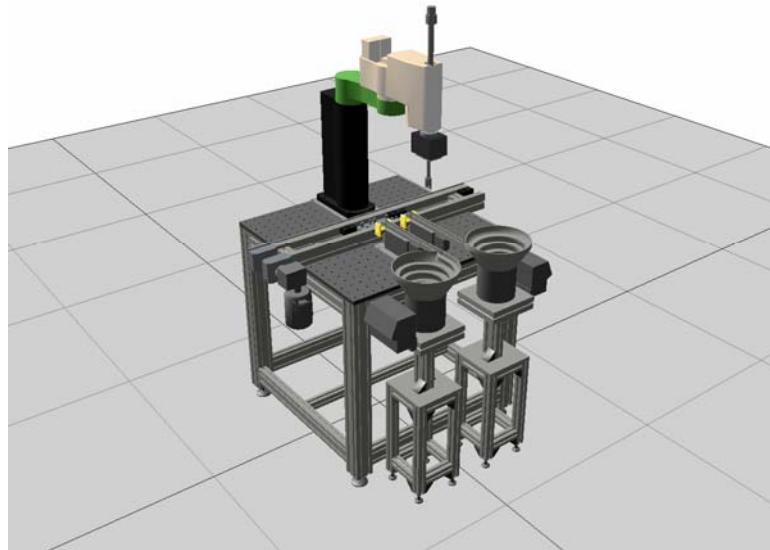
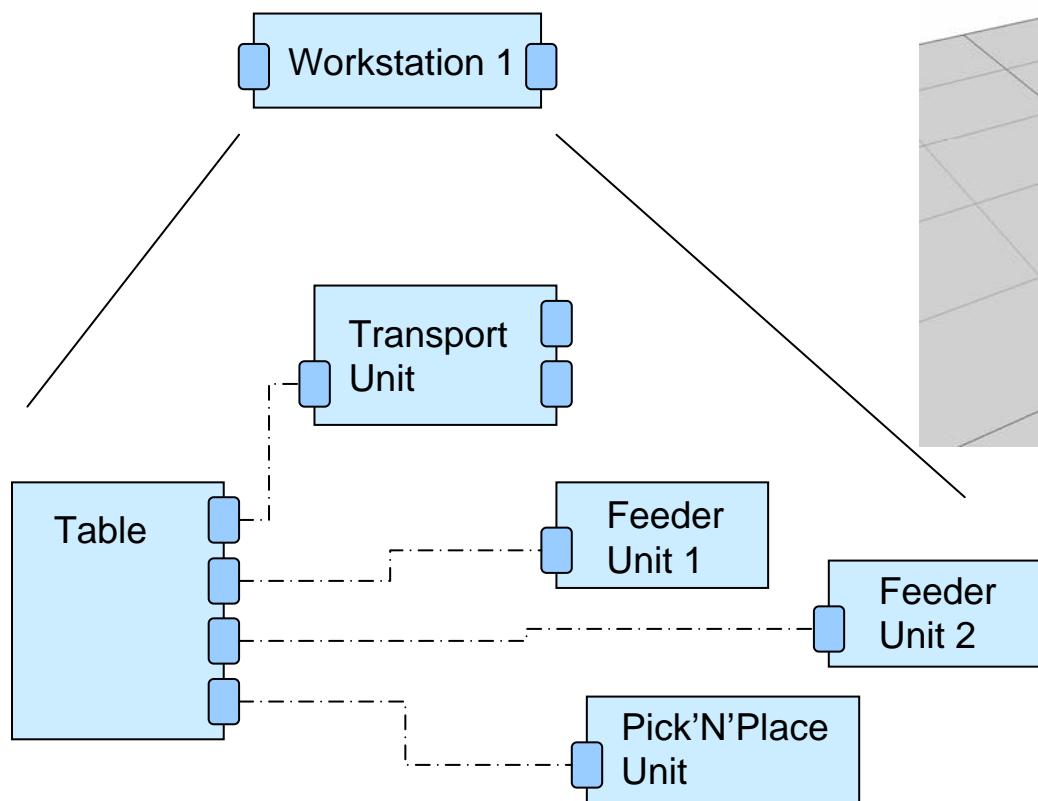
B1: Cylinder Behaviour
B2: Cylinder Behaviour
B3: Wedge Behaviour
B4: Wedge Behaviour

F1: Move Finger
F2: Move Finger

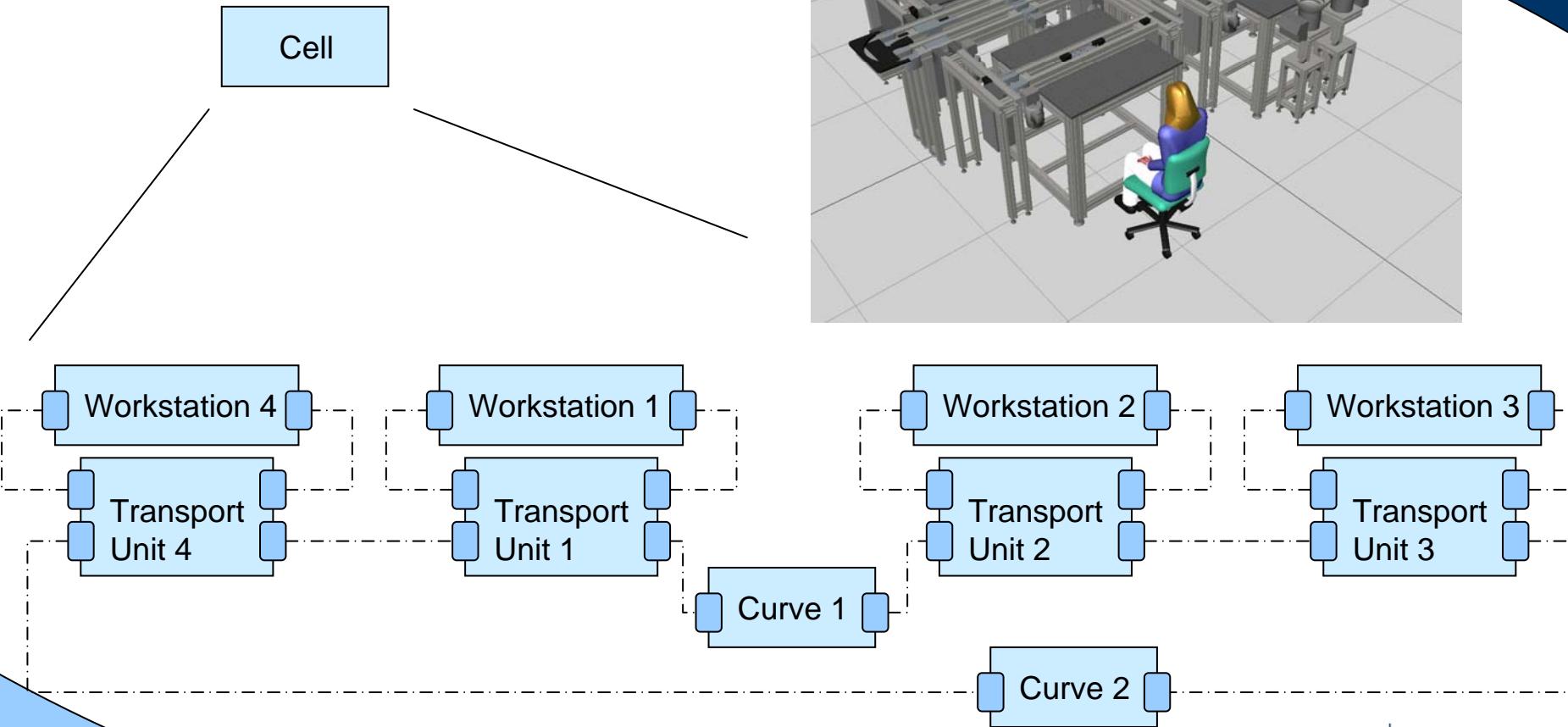
Example: Unit Configuration



Example: Workstation Configuration



Example: Cell Configuration



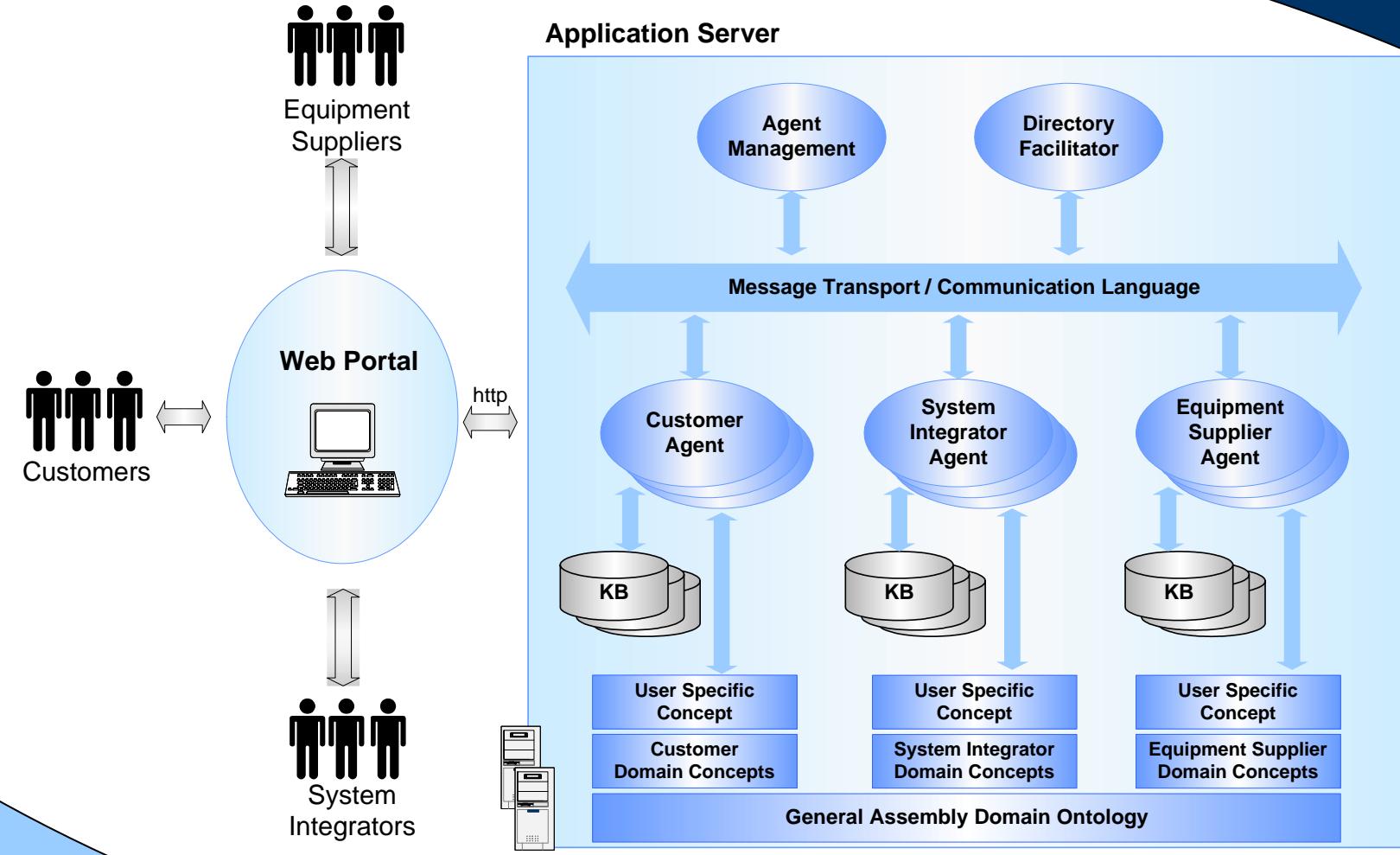
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Application Example



University of Nottingham

Agent-based Approach

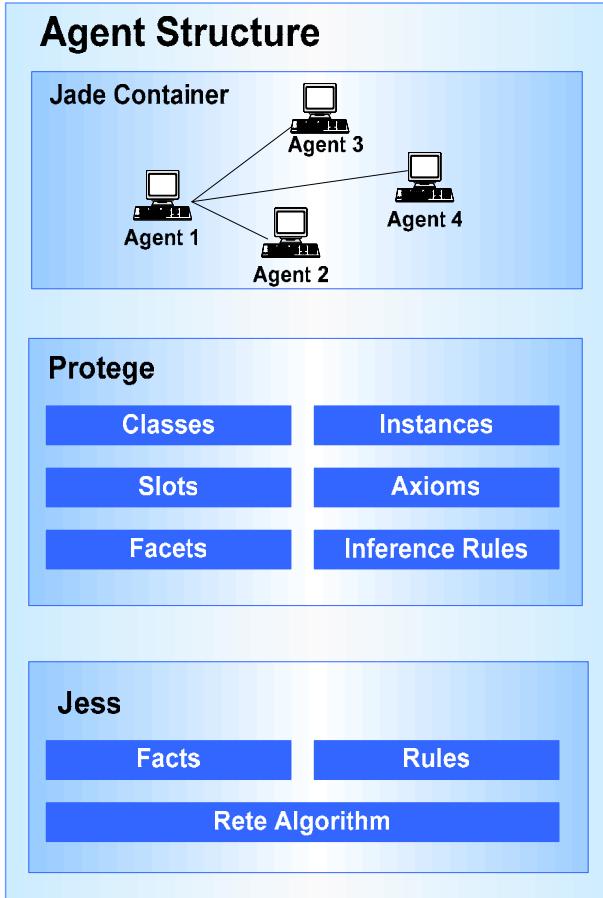


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N. Lohse et al., Protégé2005, Madrid, Spain, 18-21 July 2005

Application of Protégé

- Knowledge Base
- Knowledge and Ontology Visualisation
- Knowledge Acquisition during testing
- Constraint Checker (PAL plug in)
- Message Content Validation
- Storing of the Decision Making Model in CommonKADS notations

Agent Structure

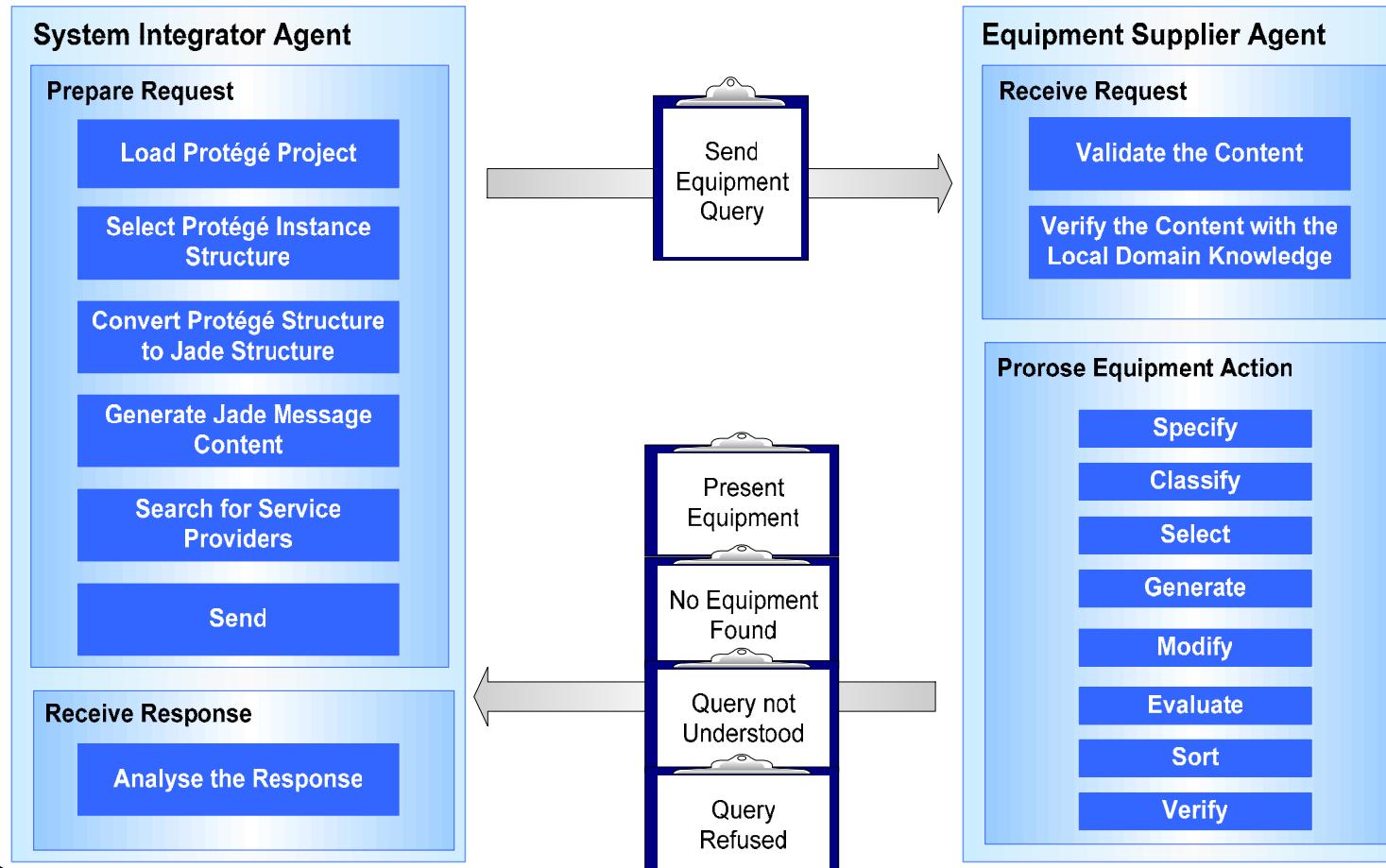


- Message transport
- Agent communication languages
- Interaction protocols (dialogues, conversations)
- Platform management (white and yellow pages)

- Use of Frame based knowledge representation
- Domain Ontology Maintenance
- Knowledge Base Editor
- Customized Data Entry Forms

- Java Expert System Shell
- Rule based reasoning engine

Example Agent Communication Scenario



Application Example (cont.)

Protégé Frame Based Ontology Specification

The screenshot shows the Protégé 3.0 interface. On the left, the CLASS BROWSER pane displays a hierarchy of classes, with 'Equipment' selected. The CLASS EDITOR pane shows the 'Equipment' class definition, which is an instance of 'STANDARD-CLASS'. It has a 'Name' field set to 'Equipment' and a 'Role' field set to 'Abstract'. Under 'Template Slots', there are four slots: 'description' (single), 'frame' (single), 'hasBehaviours' (multiple), and 'hasRelations' (multiple). The 'hasRelations' slot is expanded to show its documentation: 'Instance of Frame', 'Instance of Behaviour', 'Instance of Function', and 'Instance of EntityObjectRelator...'. Below this is a detailed view of the 'DefineProcessRequirementRule01' rule, which is an instance of 'Rule'. It has a 'Name' field set to 'DefineProcessRequirementRule01' and a 'RuleType' field set to 'internal'. The 'LHS Definition' section contains a complex query involving 'DesignConcept', 'KnowledgeRoleOcc', 'DesignConDR', 'DesignConDK', and 'Act'. The 'RHS Definition' section contains the query '(call ?this *setSlotValue ?prosReq "activities" ?act)'. A large blue arrow points from this interface to the online environment.

Inference Rule

Online Environment for the Definition of RAS

The screenshot shows the E-Race online environment. The top navigation bar includes links for 'Precision Manufacturing Group', 'Projects', 'Design Concept', 'System', 'In Box', 'My Account', and 'Log Out'. The main area displays a 3D model of an assembly system on a grid, labeled 'W/S 2 Configuration 1'. To the right of the model, a panel provides the following details:

- Description: Assembly of D E1 E2 and X2
- Operation Mode: Automatic
- Max. Process Time: 10 sec.
- Calculated Process Time: 9 sec.
- Calculated Investment Cost: 40 000 GBP
- Calculated Operating Cost: 500 GBP / Month

Below this, sections for 'Interfaces' and 'Modules' are shown, each with a list of components and their status (e.g., Robot 2, Feeder 1, Feeder 4, Tool 3, Conveyor 1, W/S Base). A large blue arrow points from the Protégé interface to this online environment.

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Conclusions

Conclusions and Future Work

Conclusions

- Strong need for a Unified Assembly System Design Ontology
- Demonstration of Proposed High Level Assembly System Design Ontology Modelled in Protégé

Future Work

- Verification in More Extensive Industrial Case Studies
- More Extensive Classification of Concepts in the different Domains

Open Issues

- Speed of Protégé as Knowledge Base Backend needs to be improved.
- Management of large knowledge Bases