# Towards a Unified Assembly System Design Ontology using Protégé

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## Introduction

The current trend in product development is moving towards ever shorter product life-cycles and ever increasing functional complexity. For example mobile phones are obsolete within one year of their introduction to the market. At the same time every new generation of mobile phone needs to provide more functions while maintaining or decreasing its size. Manufacturing and design methodologies are needed that can rapidly respond to the challenges imposed by fast changing highly customised products.

Assembly is the process of putting all the components of a product together and forms eighty per cent of the cost of manufacturing a product, this is where the greatest competitive advantage can be gained by introducing more responsive manufacturing paradigms. Modularisation of manufacturing resources is one of the cornerstones of paradigms addressing the challenges of current and future market demands.

Key success factors for these new manufacturing solutions are design frameworks that allow the rapid design of new products and their production facilities. The challenge for such design frameworks is the integration of geographically dispersed stakeholders and state-of-the-art design tools into one common platform. To enable an effective exchange of knowledge within such a framework it is of utmost importance to have a unified ontology that supports all the design activities across the entire design process.

The authors are currently involved in several major European projects in the assembly system design domain including: E-Race and EUPASS. E-Race is a EUREKA! Factory project addressing the need for an online environment that facilitates the collaborative design of assembly systems. EUPASS is funded by the European Commission within the Sixth Framework Program. The objective of EUPASS is the development of Evolvable Ultra-Precision Assembly Systems that address the manufacturing challenges of the future. The authors have also previously been major partners in Assembly Net a thematic network project funded by the European Commission to integrate precision assembly research in Europe.

All these projects are underlining the need for a unified ontology for the assembly domain. Several ontologies have been proposed within the area of assembly or in related areas. None of them however is capable of supporting all the decisions during the design of assembly systems. Hence an ontology is presented to support the industrial need.

## Ontology Definition

The design process of assembly systems has been modelled using the CommonKADS approach, which defines three levels of knowledge: task knowledge, inference knowledge, and domain knowledge (see Figure 1). The task knowledge level defines the reasoning tasks required to achieve a specific goal. The inference knowledge level defines what inferences are needed to fulfil the reasoning tasks. The domain knowledge level defines all the specific concepts needed by the inferences. All three levels have been formalised in Protégé to allow the dynamic definition and adaptation of the assembly system design process. Standard inferences have been defined to simplify the definition process. The design tasks have also been defined and classified. The main focus however is on the definition of the domain knowledge since it builds the foundation of all the decision making and reasoning during the design process.

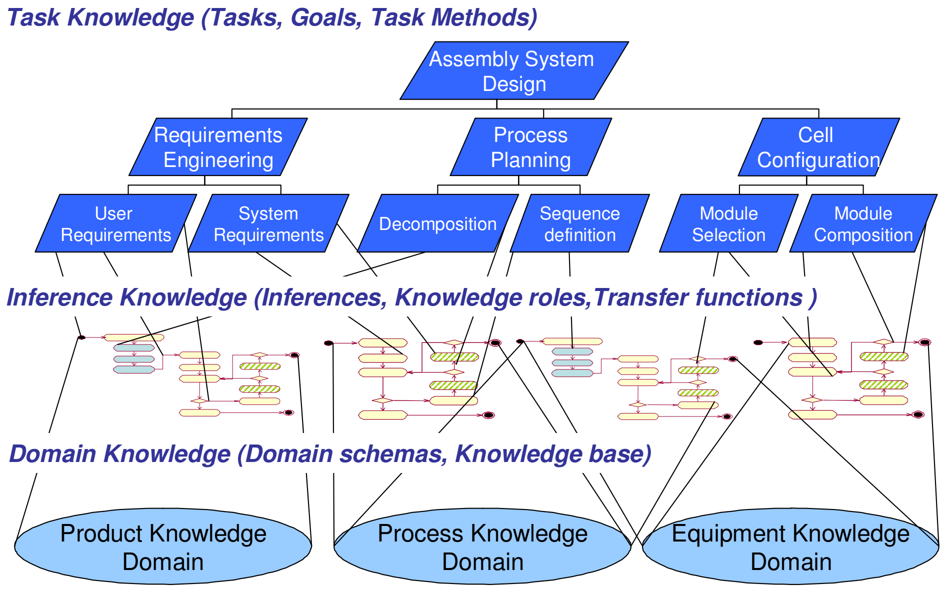


**Figure 1 CommonKADS model of the assembly system design process**

The proposed ontology model for the domain knowledge has three representation levels: the underlying knowledge representation level, the ontology concept level and the instantiation level (see Figure 2 left side). The knowledge representation level defines how the different concepts, attributes, constraints and rules are implemented. A frame based knowledge representation has been chosen to define the concepts and there attributes in an object oriented manner. The specific model constraints are expressed as axioms and the design decisions are modelled as inference rules.

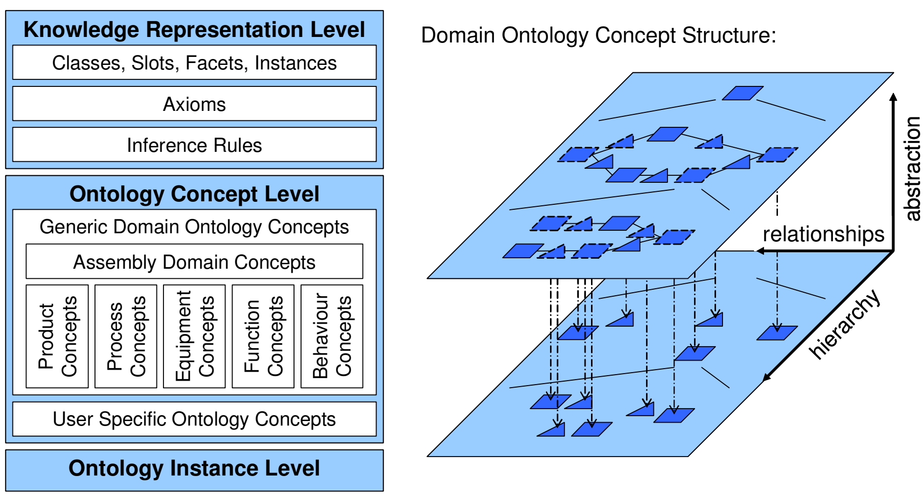


**Figure 2 Domain ontology structure**

At the ontology level all the specific domain concepts, attributes, constraints and rules are defined. The domain ontologies are divided into generic and user specific concepts. This allows all the design decisions to be based on generic concepts while at the same time providing a mechanism to enable different stakeholders to define their own specific terminology and concept interpretation. The generic domain ontology is separated to define some basic concepts that provide the structure for more specific domain ontologies. Each ontology is defined as a separate model that can be maintained and updated independently. Naturally there are some interdependencies between the different domain ontologies, but they can be limited and by doing so make it much easier to evolve the ontologies by incorporating new concepts and attributes in the future.

The basic model is defined along three axes: relationships, hierarchy, and abstraction (see Figure 2 right side). The relationships define how the concepts within an ontology are related to each other. The hierarchy aspect deals with the readability of the model. By defining different levels of detail it becomes much easier to define complex structures. The hierarchy is defined by grouping lower level concepts to form higher level concepts. Abstraction is defined using a super/sub-class structure and allows a gradual specification of more and more concrete models. The super/sub-class structure within the different domain ontologies defines the glossary of the assembly specific concepts and terminology.

## Ontology Application

The classes, slots, facets, and instances of the assembly ontology has been defined using Protégé 3.0. The constraints are expressed as axioms defined in the Protégé Axiom Language (PAL) plug-in. The inference rules have been defined using the definitions of the Java Expert System Shell (JESS).

The proposed assembly ontology has been implemented as part of a prototype web-enabled decision making environment for the distributed design of modular assembly systems. The aim of the prototype implementation is to test the completeness of the domain ontologies and the design methodology. All steps of the design process are initially supported by human centred decision making agents, i.e. agents providing decision making interfaces and initial advisory support. The human centred agents interact via dynamic web pages with the different users.

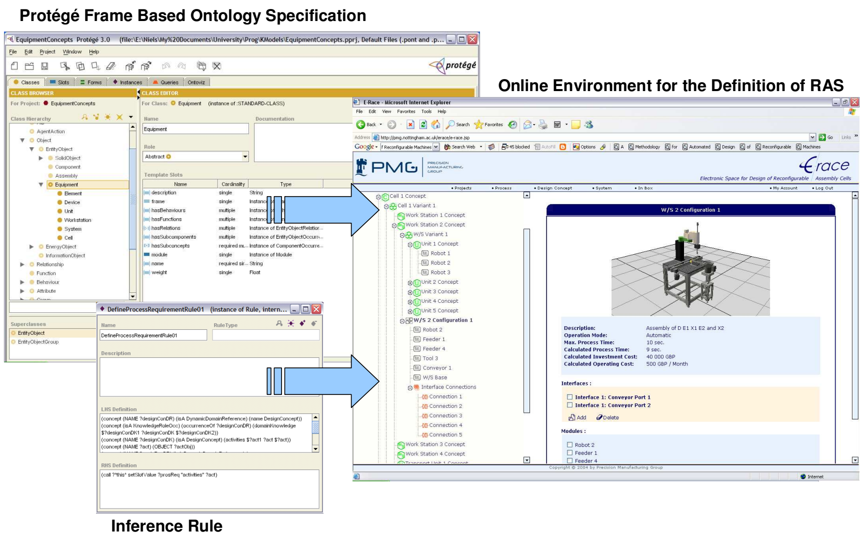


**Figure 3 Illustration of how Protégé is used for the online specification of assembly systems**

The Java Agent Development Environment (JADE) is used as middleware that provides the environment where all the agents 'live'. The design activities during the assembly system design process are executed by different agents organised in a hierarchical structure. Each agent has its own ontology and domain knowledge stored as a Protégé project. The mental model of the agents is generated based on the task and inference knowledge stored in the relevant Protégé project. The Java Expert System Shell is used to execute the inferences. A parser has been provided that translates the required Protégé instances into facts and vice versa. The JADE platform provides the message transport, communication language and interaction protocols. Another parser has been defined that translates the Protégé instances into a JADE communication language and back. The Protégé class structure is being used to validate the message content at the receiving end.

## Presentation Structure

This presentation is addressing the need for a unified assembly system design ontology and proposes a frame based ontology structure modelled in Protégé. Firstly the presentation will outline the importance of assembly in manufacturing and address the future requirements within this domain. Secondly the activities during the design process of assembly systems will be outlined based on the CommonKADS knowledge formalisation. Thirdly the proposed structure for a unified assembly system design ontology will be presented and finally the presentation will conclude with an application example of the proposed ontology.