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Collaborative Manufacturing Systems

Module I Collaborative Manufacturing Management

Ontology for Collaborative Manufacturing

Curriculum Development
of Master's Degree Program in
Industrial Engineering for Thailand Sustainable Smart Industry

Discussion and Presentation

What is the effect lack of shared understanding?

How to solve this ?

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Lack of shared understanding

The lack of ***shared understanding*** leads to:

- Poor communication within and between people and their organizations
- Difficulties in identifying requirements and thus defining of a specification of the system

Disparate modeling methods, paradigms, languages and software tools severely limit:

- Inter-operability
- The potential for re-use and sharing
- Much wasted effort re-inventing the wheel

How can we solve them?

- The way to address these problems, is to reduce or eliminate conceptual and terminological confusion and come to a ***shared understanding***.
- Such an understanding can function as a *unifying framework* for the *different viewpoints* and serve as the basis for:
  - *Communication* between *people.*
  - *Inter-Operability between systems.*
  - *System Engineering benefits as:*
    - Re-usability
    - Reliability
    - Specification

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Solution for Lack of shared understanding: Examples

SemiConductor Fabrication

Situation/Problem:

Software bought in from the outside includes a *WIP tracking system* and *production line simulation package*. The simulation package requires as input, a very large description of a model of the product flow in the factory, which incorporates various details of the WIP tracking mechanism. When new versions of the simulation package are released, or if a new supplier is chosen, the model must be converted to a new format. This conversion is both time consuming and error prone.

Solution:

Automate the process of converting the model when new external software is introduced. This both saves time and ensures model fidelity.

- There are 3 intersecting domains of interest: *WIP tracking*, *product flow simulation*, and *the semiconductor fabrication process*.
- The approach was to develop a unifying framework which identified, defined, and named all the important concepts in this intersection.
- The models are expressed in terms of this framework and stored in an Oracle relational database.
- An automatic translator converts the models from the Oracle database into the format required by the simulation software.
- The Oracle DB is itself populated by a translator that extracts information from the WIP tracking system.
- The DB entries are automatically translated into model components required as input to the simulator, WIP system tracking entries are also automatically translated into DB entries.

(Uschold & Gruninger, 1996)

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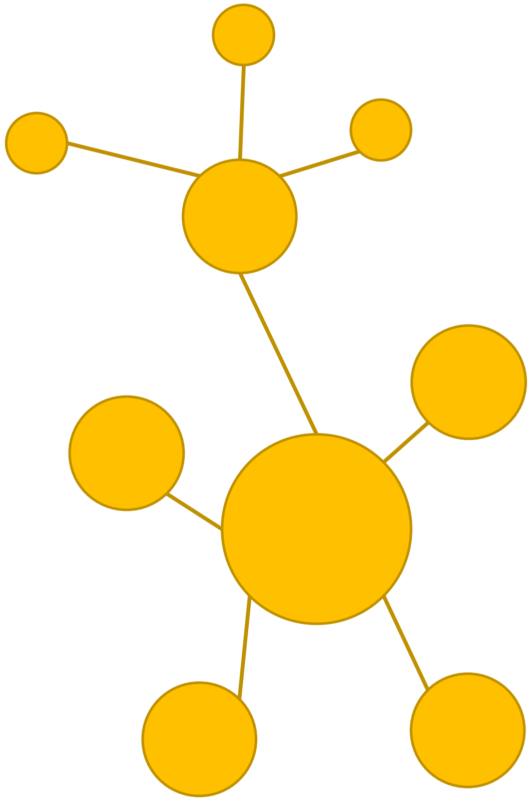
What is **Ontology**

Ontology refers to the *shared understanding* of some domain of interest which can be used as a *unifying framework* to represent selected phenomena.

Ontology necessarily entails or embodies some sort of world view with respect to a given domain.

For the world view, ***Ontology*** is often conceived as *a set of concepts* (e.g. entities, attributes, and processes), their definitions and their inter-relationships

(Uschold & Gruninger, 1996)



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Uses of ontologies

COMMUNICATION

between people and organizations

INTER-OPERABILITY

between systems

Reusable Components Reliability Specification

SYSTEM ENGINEERING

We identify three main categories of uses for ontologies. Within each, other distinctions may be important, such as the nature of the software, who the intended users are, and how general the domain is.

(Uschold & Gruninger, 1996)

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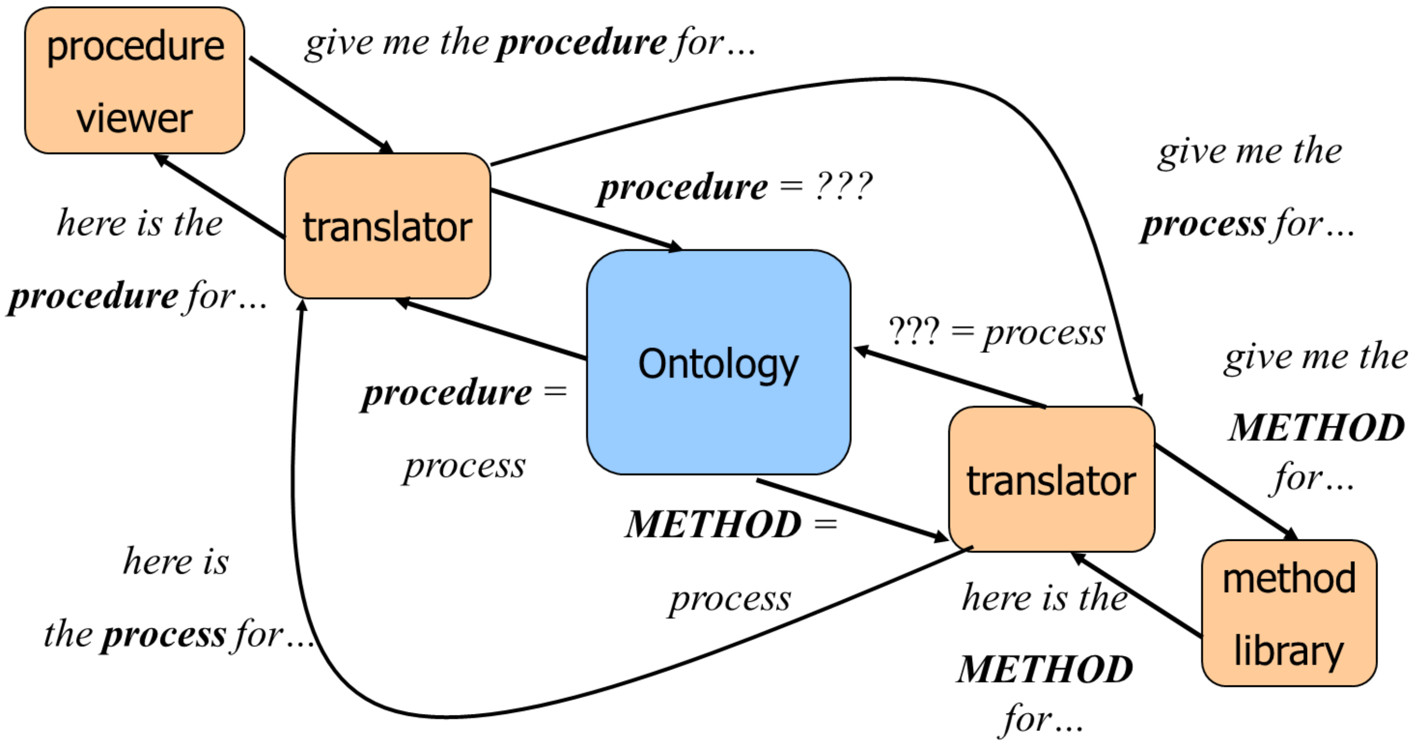
Uses of ontologies

The term ‘procedure’ used by one tool is <u>*translated*</u> into the term ‘method ‘ used by the other *via the ontology,* whose term for the same underlying <u>*concept*</u> is ‘process’.



(Uschold & Gruninger, 1996)

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A Skeletal Methodology for Building Ontologies

Proposed comprehensive methodology for ***developing ontologies*** includes:

- *Identify Purpose and Scope*; It is important to be clear about why the ontology is being built and what its intended uses are.
- *Building the Ontology;* Three aspects to building the Ontology are capture, coding, and integration of existing ontologies.
- *Evaluation*; to make a technical judgment of the ontologies, their associated software environment, and documentation with respect to a frame of reference
- *Documentation;* It may be desirable to have established guidelines for documenting ontologies, possibly differing according to type and purpose of the ontology.

(Uschold & Gruninger, 1996)

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Manufacturing Ontology

In order to improve agility and flexibility, nowadays one uses distributed approaches in *developing manufacturing control applications*. These are built upon autonomous and cooperative entities, such as those based on multi-agent and holonic systems.

In the *communication between* distributed and autonomous entities, besides the issues related to interfaces and protocols, it is important to verify that the semantic content is preserved during the exchange of messages.

These distributed entities *need to have a common understanding of the concepts* of their domain knowledge, which is given by ***a domain (or core) ontology***.

The inter-operability in distributed and different multi-agent or holonic platforms *increases the need* for **shared ontologies**, in order to allow the exchange of knowledge between those distributed platforms.

(Borgo and Leitao, 2004)

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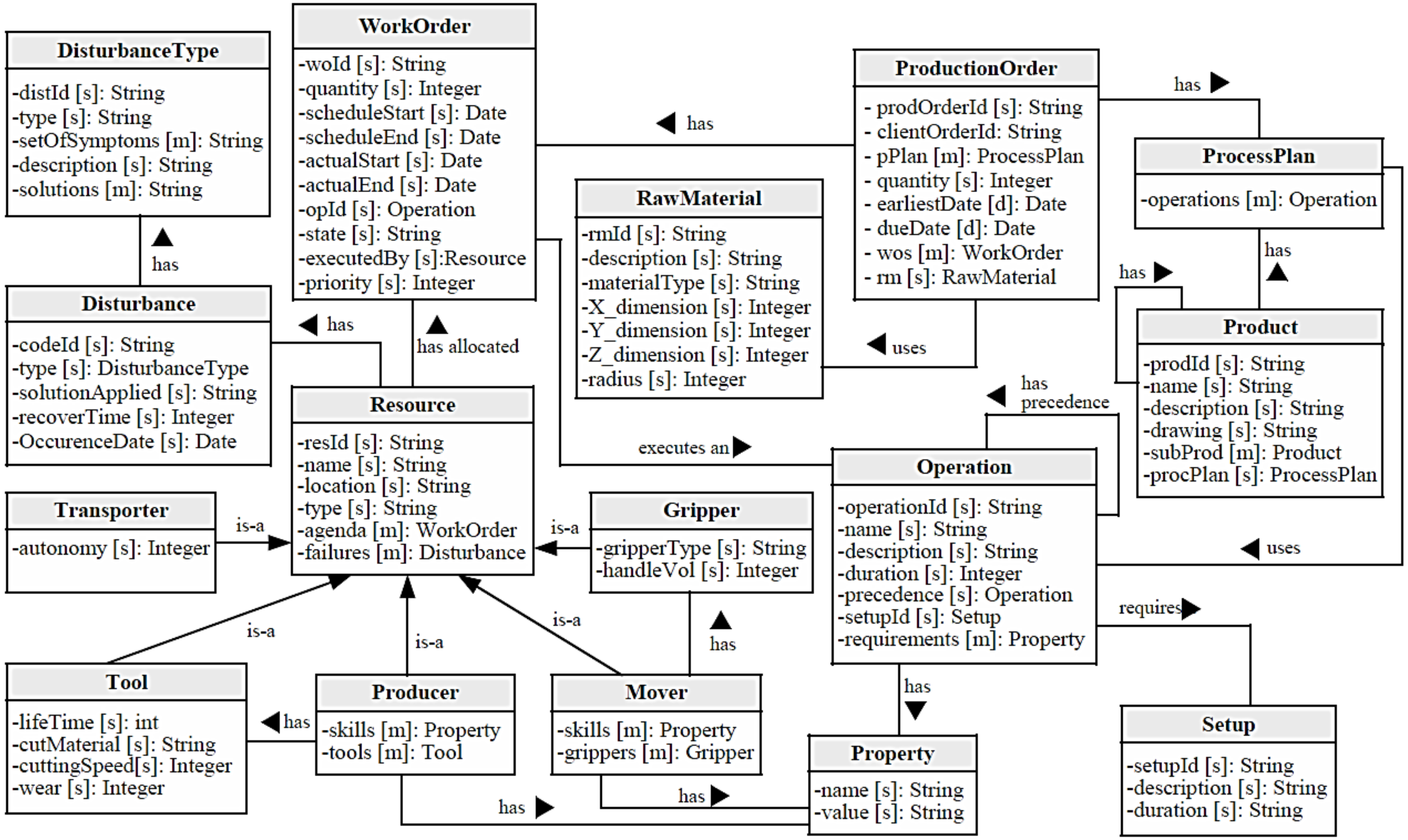
Manufacturing Ontology

ADACOR (ADAptive holonic COntrol aRchitecture for distributed manufacturing systems)

The manufacturing ontology used in ADACOR is developed through the definition of a taxonomy of manufacturing components, which contributes to the analysis and formalization of the manufacturing problem

For this, one must fix the vocabulary used by the distributed entities *over the ADACOR platform* and the meaning of each term.

The diagram is restricted to the r*elationships between simple manufacturing components* used by the manufacturing control system.



(Leitao and Restivo, 2002)

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Ontology for collaborative manufacturing

Alignment of service-oriented framework with service-dominant logic

ITs alone have not produced sustainable performance advantages, but that firms have gained advantages by strategic ***planning-IT integration***.

Effective information system building for collaborative manufacturing should incorporate institutional analysis from organization studies.

The essential alignments between service-dominant (S-D) logic and service-oriented framework & between collaborative infrastructure and Service-Oriented Architecture (SOA) should be considered.

Several **design guidelines** for an ontology of service-oriented collaborative manufacturing

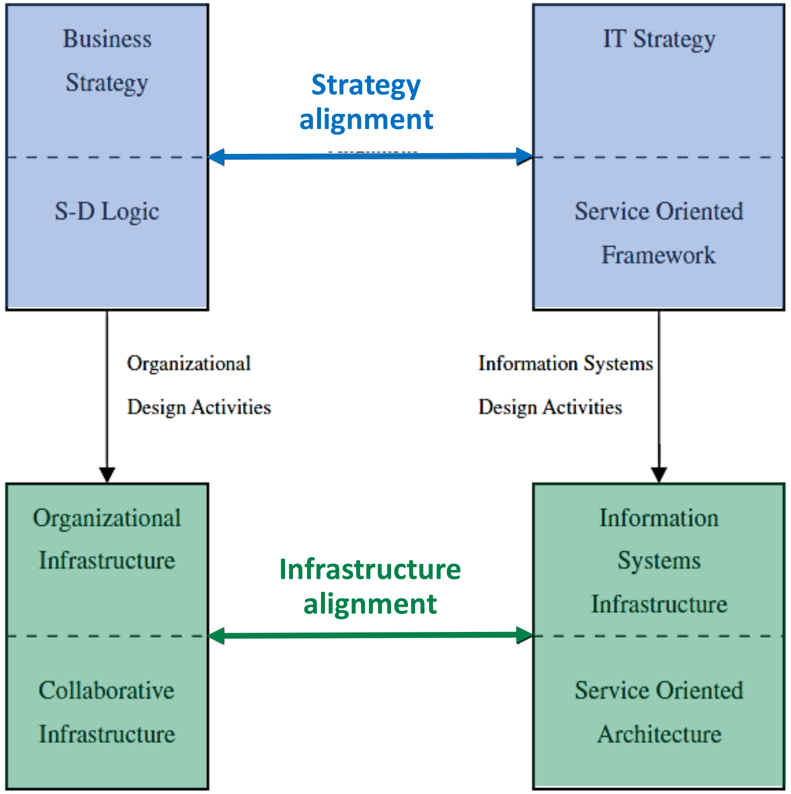
Guideline 1: Manufacturing capability and distribution capability should be modeled as operant resources, which are fundamental units for service exchange.

Guideline 2: The customer should be modeled as an operant resource, which is an active participant in relational exchanges and coproduction.

Guideline 3: A general contractor should be modeled as an operant resource to make the proposal, agreement, and value judgments.

Guideline 4: Goods are a distribution mechanism for service provision.

Strategy alignment and infrastructure alignment



(Yan et al., 2010)

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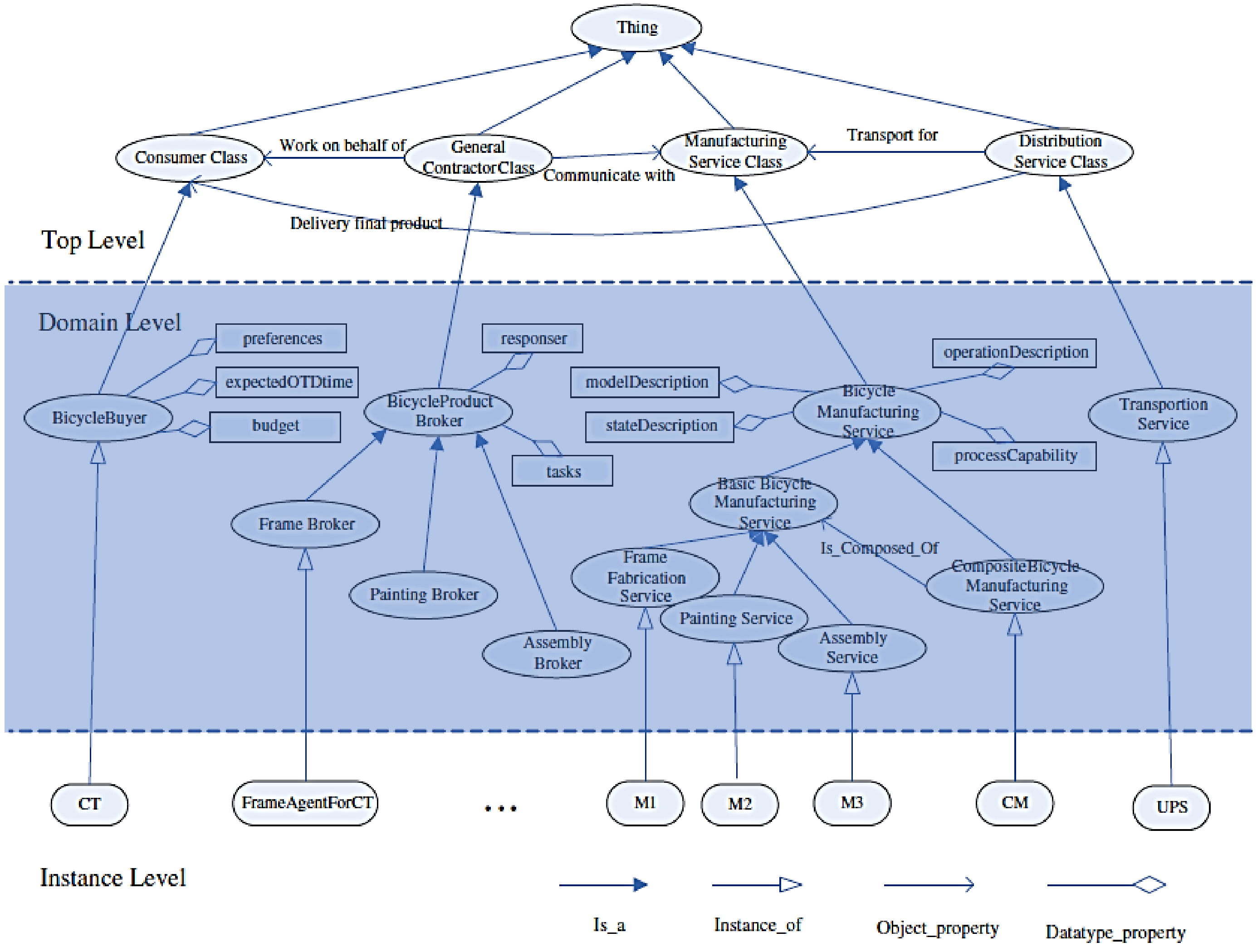
Ontology for collaborative manufacturing

Alignment of service-oriented framework with service-dominant logic

The ***ontology*** of collaborative manufacturing has been designed in four key based classes: Consumer Class, Product Broker Class, Manufacturing Service Class, and Distribution Service Class.

The ontology which represents the *collaborative manufacturing* for customized production is produced in three levels: Top Level, Domain Level, and Instance Level.

Web Ontology Language (OWL) could be used to model *collaborative manufacturing* from this schema. The main advantages of OWL are efficient reasoning support, sufficient expressive power, and convenient expression.



(Yan et al., 2010)

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Ontology for collaborative manufacturing

Alignment of service-oriented framework with service-dominant logic

Case Study: Customized bicycle buying scenario

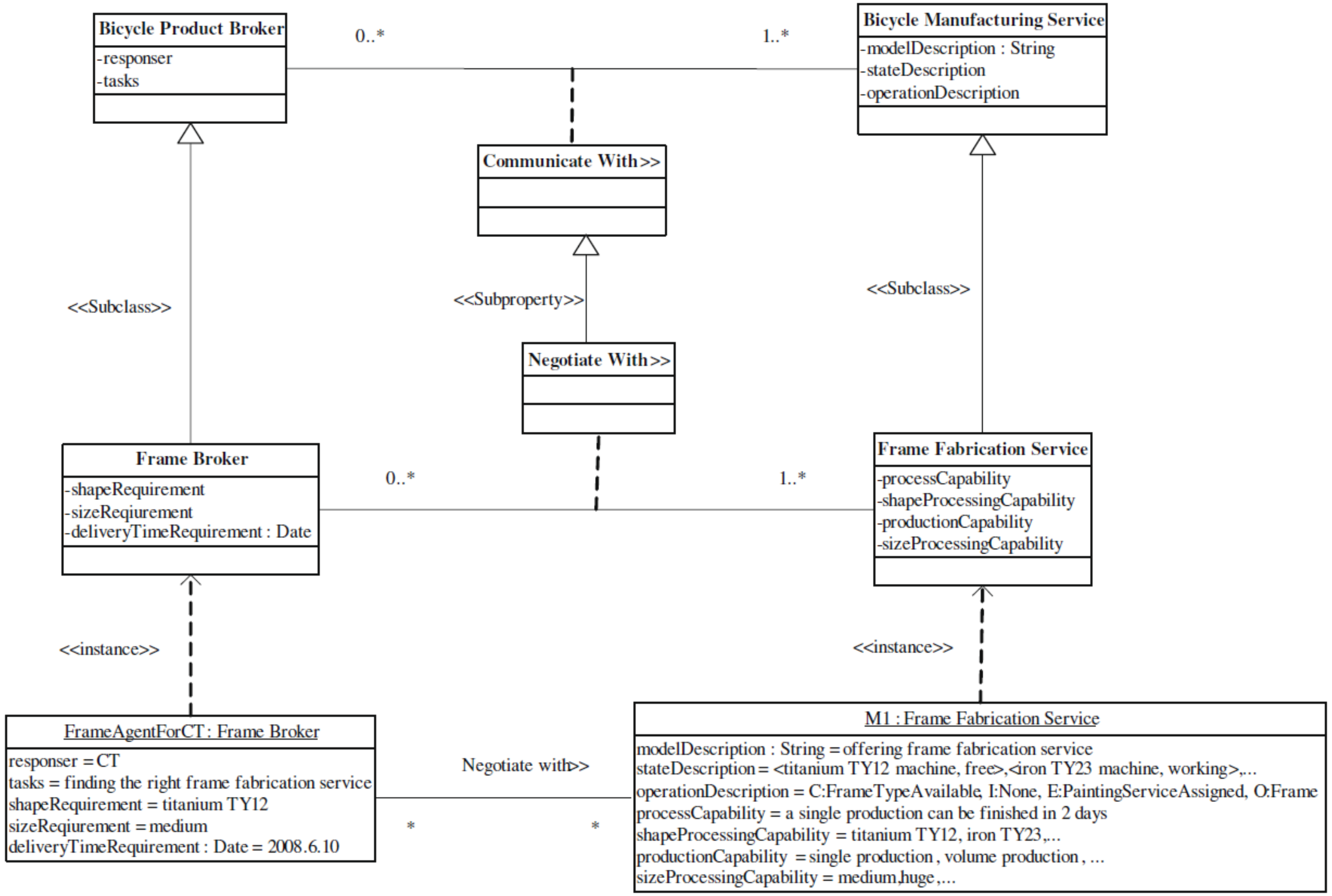
In *collaborative manufacturing*, each producer focuses on their core competence, so as to minimize their production costs and market mediating costs.

The major components are the *manufacturing service grid*, *web services*, and the *product broker.*

The ontology is based on the Interact-Service-Propose-Agree-Realize, which the scenario and transaction illustrated in three stages: Proposal, Agreement and Realization

FrameAgentForCT acts on *behalf of customer* CT, communicates and negotiates with the Frame Fabrication Service.

The Frame Agent and Frame Fabrication Service M1 reach an agreement on frame shape, frame size, delivery time, and so forth.



(Yan et al., 2010)

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Ontology for collaborative manufacturing

Ontology-based framework of knowledge integration

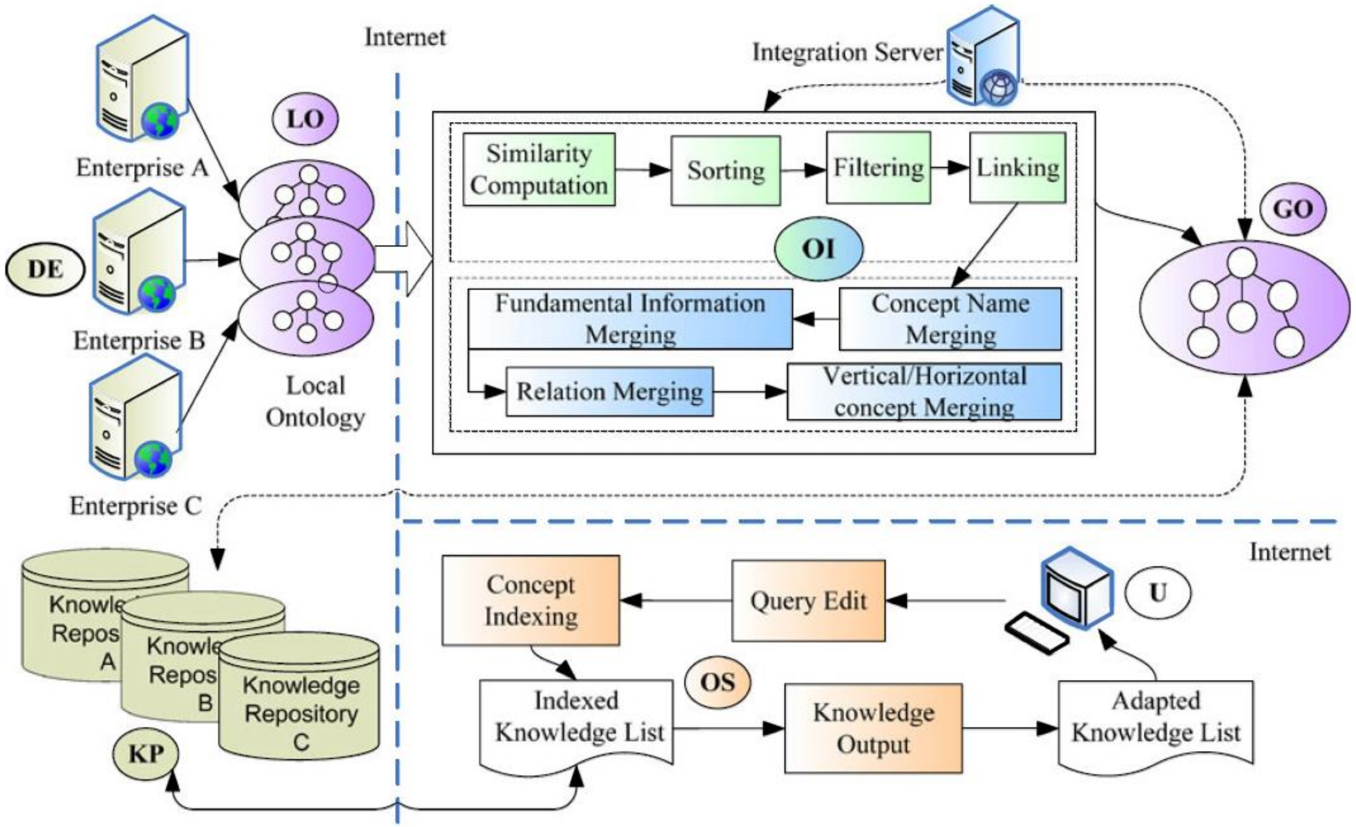
A domain ontology can *comprehensively represent knowledge of one area*

An integrated ontology can *represent all knowledge* of various repositories.

Problem of *optimization of integrating the product knowledge* between distributed collaborative enterprises can be solved by ontology.

All of the core elements of the *integration framework* includes:

- DE: domain enterprise
- LO: local ontology
- GO: global ontology
- OI: ontology integration
- OS: ontology searching
- U: the collaborative manufacturing environment to denote the user
- KP: knowledge repository stores the physical knowledge



(Yang et al., 2010)

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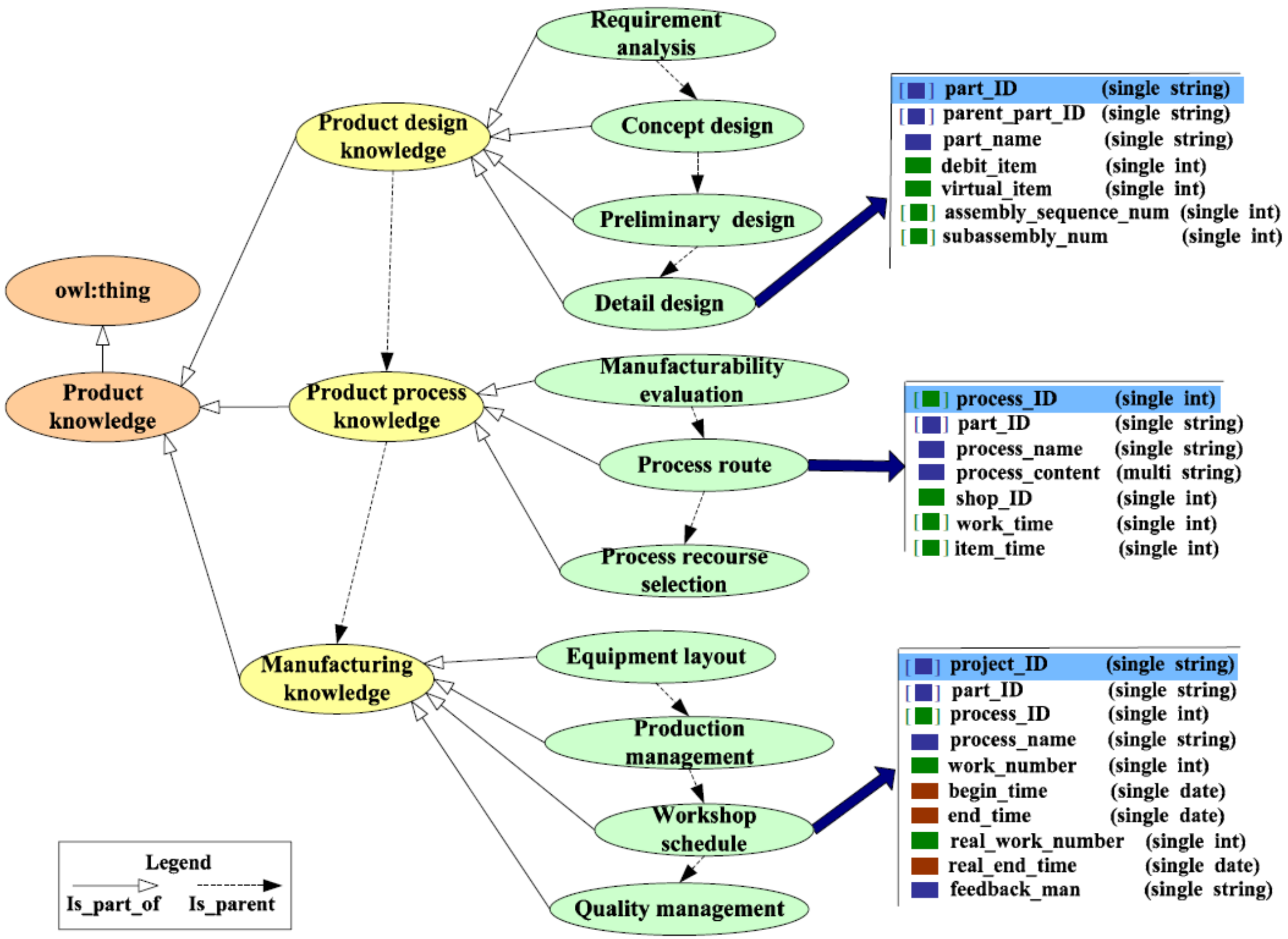
Ontology for collaborative manufacturing

Ontology of product knowledge

An ***ontology*** of product knowledge is established to describe concept, attribute, instance and relationship among knowledge concepts within the *collaborative manufacturing*.

The ***ontology*** is composed of product design, process planning, and manufacturing knowledge. The sub concepts of these stages are identified as:

- Sub-concepts from ***product design knowledge*** are *combined with* requirement analysis, conceptual design, preliminary design, and detail design.
- Sub-concepts from ***product process knowledge*** *are* manufacturability evaluation, process route and process resource selection.
- Sub-concepts from ***manufacturing knowledge*** include equipment layout, production management, workshop schedule, and quality control.



(Yang et al., 2010)

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Ontology for collaborative manufacturing

Ontology schema of product knowledge

The ***ontology schema*** of product knowledge is used by individual enterprises to build their *own domain ontology* with address of the *physical knowledge*. The schema includes:

Concept name: describing an explicit or tacit knowledge concept name.

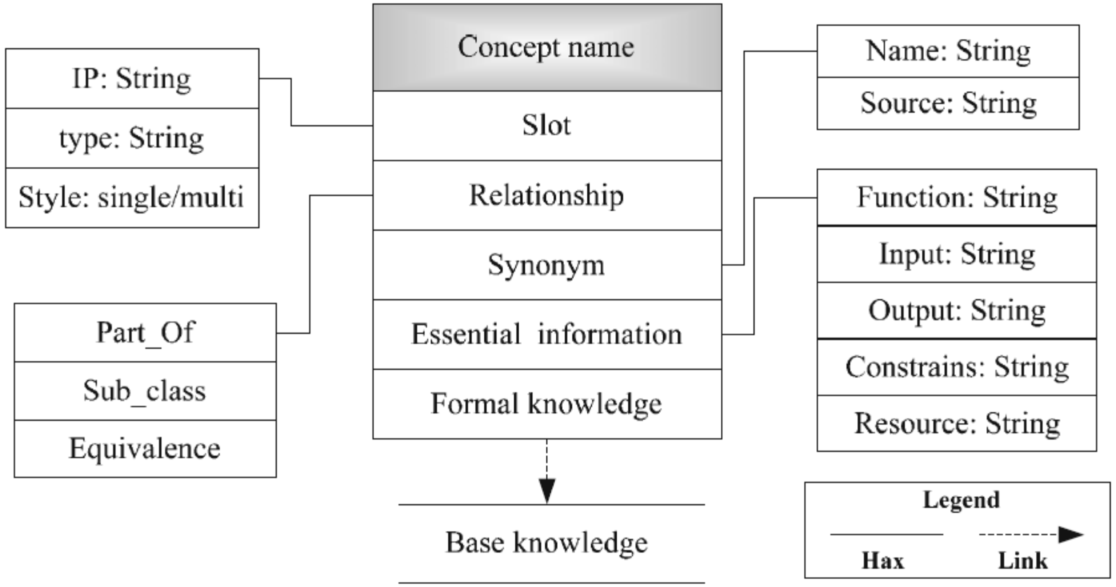
Slot: some connatural attributes of a certain concept to ensure that it is easy to understand and specify.

Relationship: the relation between concepts that includes “part_of”, “sub_class”, and “equivalence”.

Synonym: describing the same semantic using different concept terms.

Essential information: presenting information related to a concept, including function, input, output, constraint, and resource.

Formal knowledge: recording the linking address in depth knowledge that contains detailed descriptive documents for, or examples of, a certain concept.



(Yang et al., 2010)

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Ontology for collaborative manufacturing

Method process of ontology integration

A ***method of ontology integration*** based on the *similarity matching* and it is composed of two phases: ontology mapping and ontology merging

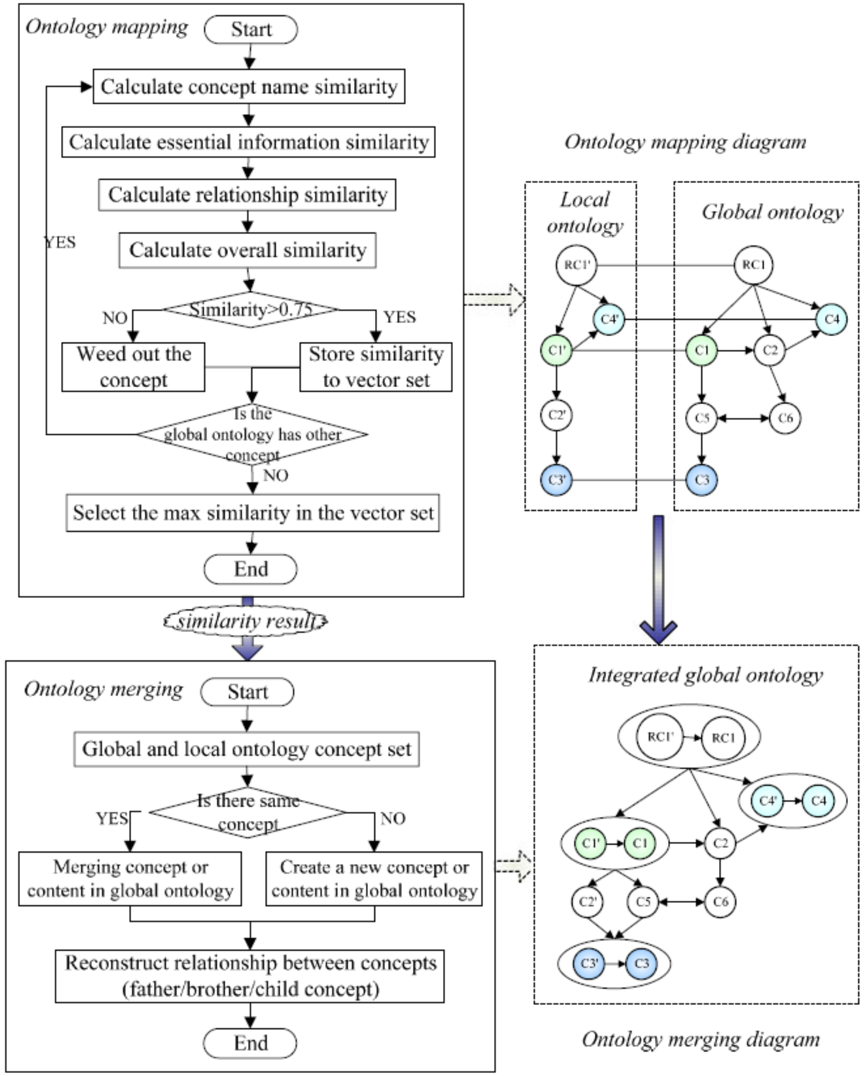
Ontology mapping conducts a similarity matching for concept names and considers the similarities of essential information and relationship to precisely identify the similarity between concepts.

Ontology merging process is described when we *merge concept content* and *relationships* based on ontology-mapping results.

Step 1. Concept content reconstruction: Concept content reconstruction must first consider whether local ontology maps with global ontology.

Step 2. Relationship reconstruction:

- Hierarchical relationship merging: increasing father concept relationships in the global ontology.
- Process relationship merging: increasing brother concept relationships in the global ontology.



(Yang et al., 2010)

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Ontology for collaborative manufacturing

Case study with the implemented software

An *implementation model* is divided into five parts: information layer, integration layer, business layer, access control layer, and implementation layer.

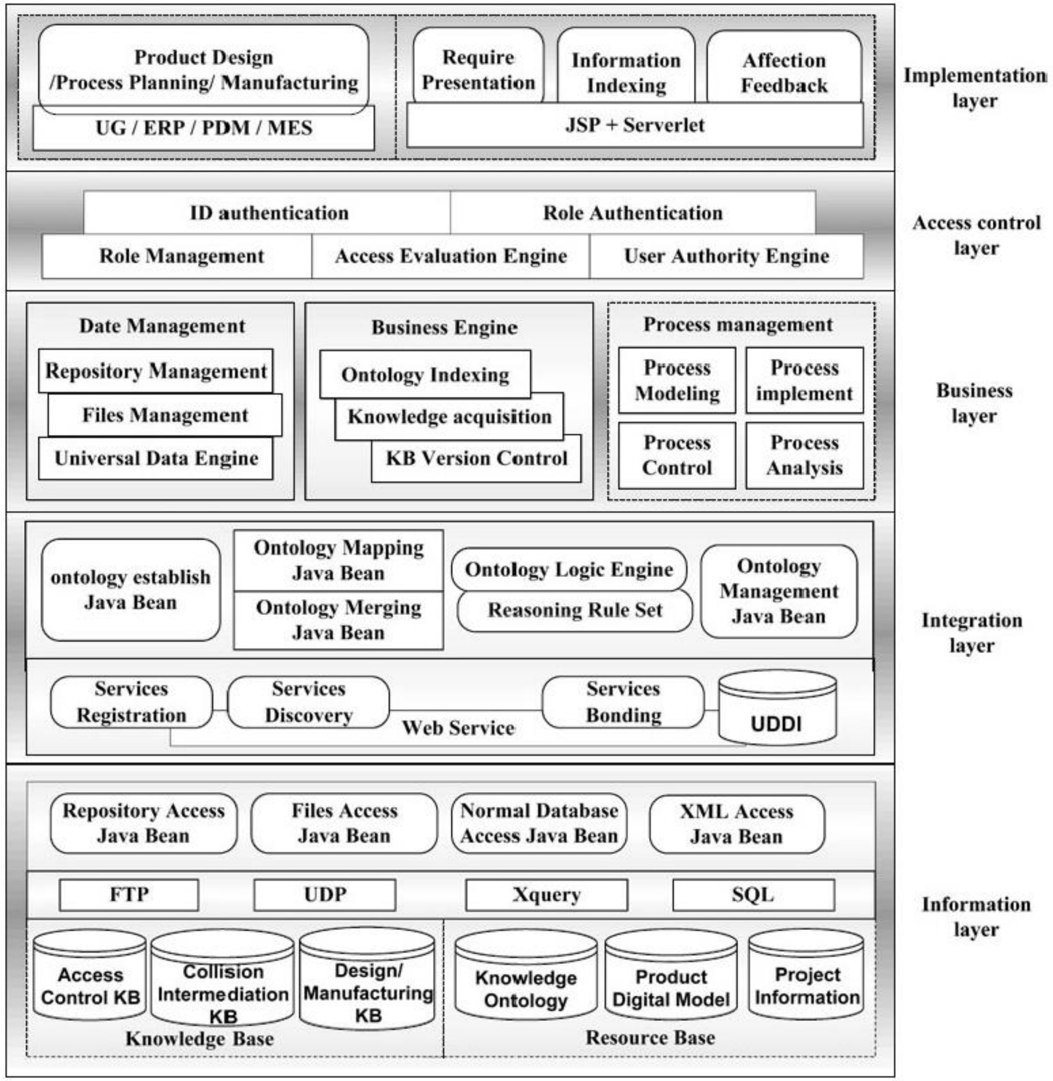
Information layer provides places to storage of various data and knowledge and some functions to access to this information.

Integration layer provides a mechanism of information integration to shield heterogeneous of distributed data. This layer consists of two parts: ontology-based and web services-based integration.

Business layer provides a uniform mechanism of data management, business management, and process management for distributed collaborative partners.

Access control layer is used to guarantee the confidentiality and the integrality of the collaborative environment through authentication.

Implementation layer provides a uniform collaborative environment of the software for partners by means of the networked technique to achieve indexing and sharing of technological information.



(Yang et al., 2010)

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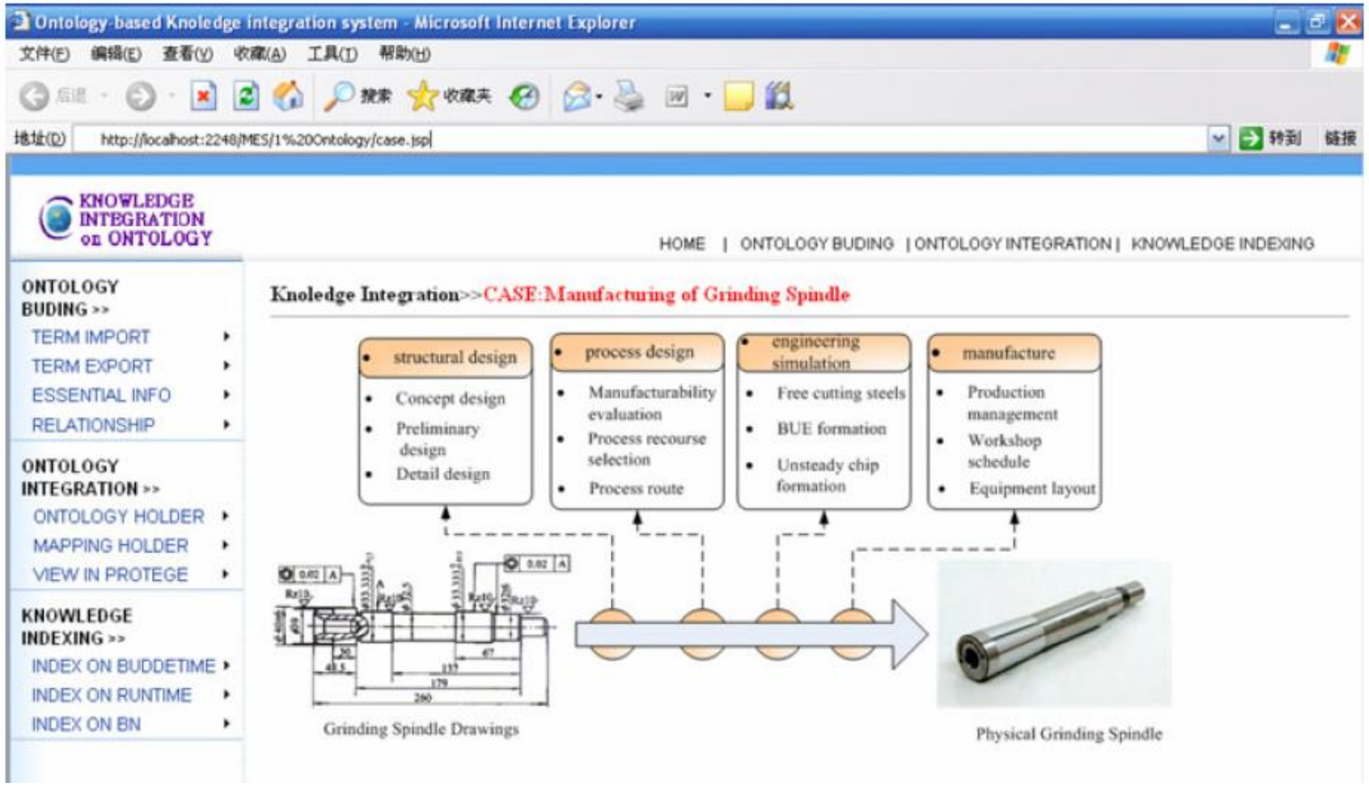
Ontology for collaborative manufacturing

Case study with the implemented software: Collaborative manufacturing of a grinding spindle

To specify the function of prototype system, a collaborative manufacturing of a *grinding spindle* was described in Figure.

All *manufacturing processes* consist of structural design, process design, engineering simulation, and manufacturing.

Concerned engineering knowledge includes product structure, manufacturing resource, process rules, and tasks.



(Yang et al., 2010)

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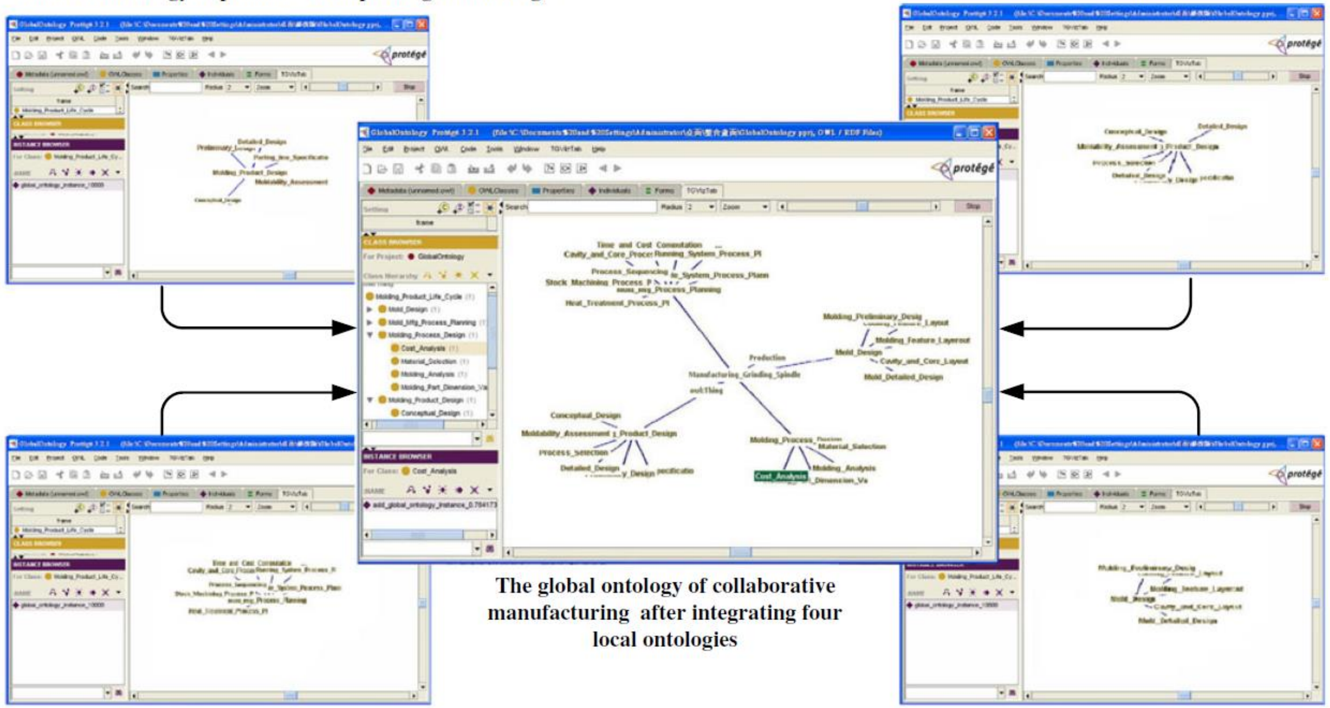
Ontology for collaborative manufacturing

Case study with the implemented software: Interfaces of ontology integration

The ***interface of ontology integration***, which is consisted of integrated global ontology concepts and four local ontologies.

All of the ontology indicates the knowledge contents.

The integrated global ontology is originally *supplied by* hegemonic enterprise in collaborative manufacturing, including the concepts of product design, product process planning, and manufacturing scheduling knowledge.



The local ontology of product concept design knowledge

The local ontology of Product process knowledge

The global ontology of collaborative manufacturing after integrating four local ontologies

The local ontology of product detail design knowledge

The local ontology of manufacturing knowledge

Conclusion: the *ontology-based framework* of *knowledge integration* provides comprehensive concepts and knowledge connections to effectively integrate an individual enterprise's knowledge integration, increasing reuse ratio of product knowledge and reducing product development cost and cycle time.

(Yang et al., 2010)

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Activity: Self Study (Ontology for collaborative manufacturing)

After reading the article: ***"An ontology-based product design framework for manufacturability verification and knowledge reuse"*** **(Li et.al, 2018)**

Discussion:

- The methodology of Ontology-based product design framework (Section 3)
- The implementation of Ontology-based product design for case study (Section 4)

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