GNOSIS Research Activities at Osaka University

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Introduction

In the GNOSIS project, we have been conducting the research on establishing foundation of knowledge systematisation of knowledge for synthesis based on Ontological Engineering in AI research. An ontology is an explicit specification of conceptualisation, and thus facilitates systematisation of knowledge and its reuse [1]. Our research activities includes (1) investigation of fundamentals of functional knowledge, (2) development of a design support system based on ontologies, and (3) development of methodologies and tools facilitating knowledge systematisation. This article summarizes the first and second activities.

Motivation and goal

During the conceptual design of artefacts, designers select a few function-realization ways depending on the context or goals they are engaged in among various alternatives. For example, when they connect two things, there are many alternative ways such as a way using bolts and nuts, welding way, etc. If a designer is interested in the decomposability of products, then he/she might select the bolts and nuts way rather than welding one.

One of our research goals is to develop such a system that can help designers select appropriate function-realization ways for target functions. The requirement specifications for the system include provision of wide range of function-realization ways and flexible presentation of the ways adaptively to the designers' viewpoints or context in the design process.

In order to achieve this goal, we realized the necessity of knowledge systematisation. For example, the knowledge about connection ways, which is fundamental in design and manufacturing, is understood to be too far from the systematisation to use for this purpose. In fact, the knowledge is scattered around gluing, welding, etc. The knowledge tends to lack consistency of viewpoints, to be ill-structured, and to be categorized by the non-fundamental characteristics which are derived from deeper principles. As is seen in TRIZ theory[2], utilization of various knowledge across multiple domains plays the role of a driving force to facilitate creative design, our system might be useful for helping designers come up with creative design.

Fruits of the research

1. Ontologies for functional knowledge

We first identified several types of knowledge related to function-realization ways and established layers of functional knowledge shown in Figure 1.

So-called top-level ontology which represents

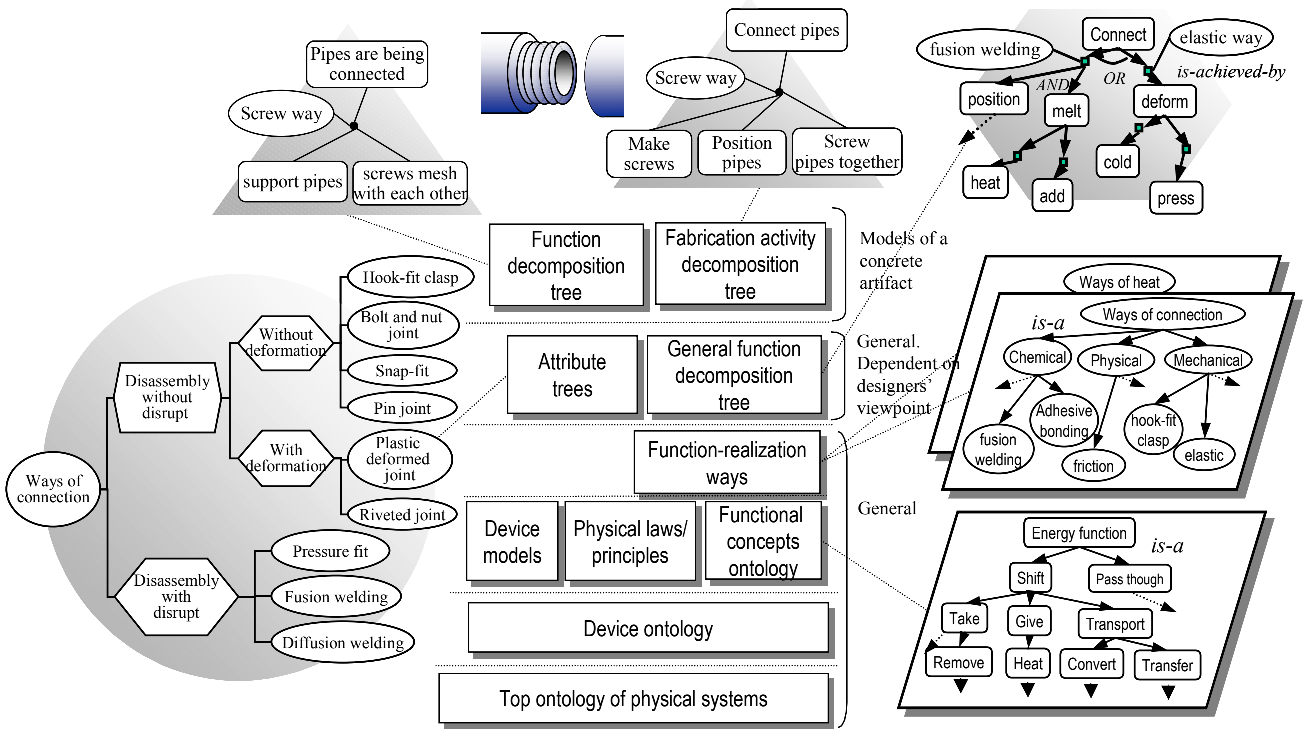

Figure 1. Types of functional knowledge and their layers

fundamental categories (e.g., entity, state, time) that physical systems consist of. [3] stays at the bottom layer to govern all the ontologies in the upper layers. Next is the device ontology which is effectively the basis of our knowledge systematization. The device ontology specifies the device-centered view of artefacts. It defines "device", "function", "way", "method", and so on using fundamental concepts defined in the top ontology. We define "function" as a result of interpretation of behaviour of the component under an intended goal [4]. The key idea of our systematisation of functional knowledge is formulation of "*way*" of function-realization. A function can be achieved by the different groups of sub-functions (so-called functional decomposition [5]). We call a group of sub-functions constrained by the relations among them "*a functional method*" of a realisation. On the other hand, we call the basis of the method "*a functional way*". The *way* is the result of conceptualisation of the physical law, the intended phenomena, the feature of physical structure, or components assumed in the decomposition.

At the third layer, the functional concepts ontology defines generic functions of devices [4,6]. It consists of three categories of functional concepts, that is, *base-function* shown in the figure, *function type*, and *meta-function*. Using the functional modelling language FBRL (abbreviation of a Function and Behaviour Representation Language) [4], we can define general meaning of a base-function independent of target objects and devices.

Using these functional concepts as a vocabulary, the *function-realization ways* can be described (at the forth layer). In general, there are many "*ways*" for a function. The *ways* can be generalized and systematized as an is-a hierarchy. With the help of GNOSIS members, we elaborated on the *connection function* in this research. The main results include organization of knowledge about connection as partly shown in the figure according to a finding that principle knowledge behind the connection activity/phenomena nicely determines the characteristics of *function-realization ways*.

The knowledge at the fifth layer can be generated from the *function-realization ways*. For selection of *ways* in design, *ways* are classified by value of attributes (so-called decision tree). Each leaf node represents a *way*. The structure of the tree depends on the viewpoints. The tree in the left of the figure shows an *attribute tree* according to decomposition. On the other hand, *general functional decomposition tree* shown at the upper right in the figure consists of possible *ways* of achievement of a function in OR relationship.

The knowledge at the sixth layer is a model of a concrete system. It includes a *concrete function-decomposition tree* and a *concrete fabrication activity decomposition tree*. In the figure, these trees of the pipes connected using the screw way are shown.

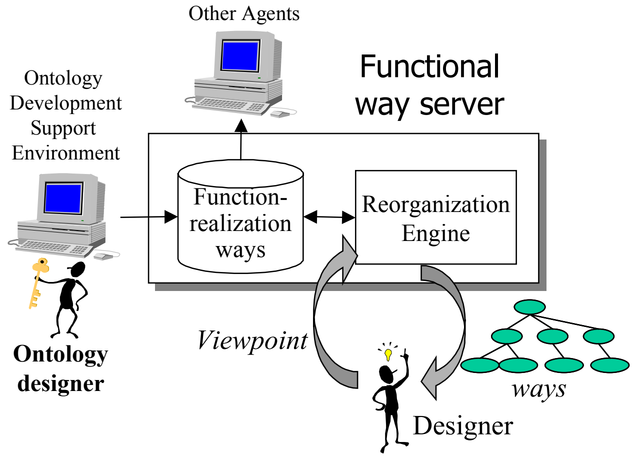

Figure 2. Framework of the functional way server

2. Design support system based on the ontologies (the functional way server)

The functional way server supports conceptual design of engineering devices, providing suitable realization ways of the function that the designers consider. This was enabled by the ontology and systematisation of related knowledge. Given a required function and a viewpoint of the designer, the server organizes the function-realization ways knowledge in a manner suitable for the viewpoint in a tree structure. After the designer selects a way, the system generates a concrete function decomposition tree of the product and a concrete fabrication activity decomposition tree.

The server provides a wide range of ways in different domains and then facilitates innovative design. Furthermore, because the server can track effects of decisions made by both the product designer and the manufacturing designer, the server facilitates negotiation in a concurrent design team.

Reference

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