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METHOD OF WEB CONCEPTUAL DESIGN BASED ON A SHARED CONTEXT OF KNOWING DESIGN ARTIFACTS

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ABSTRACT

The research described in this paper focuses on the development of Internet technology for web conceptual design on the basis of shared knowing and representation of design artifacts. The shared representation of design artifacts results in special type of knowledge considered as different interpretations of functional meaning and content of each artifact. Being defined as multiple Function Means patterns (FM-patterns) these interpretations are created by distributed designers for own purposes. When designing the product, individual knowledge of designers is combined to infer new knowledge. In order to illustrate the proposed approach, web-interface for creating FM-patterns and rules for functional, behavioral and design coupling design artifacts are described.

Keywords: Design Artifact, Shared Context and Function Means Pattern

1. INTRODUCTION

Collaborative development of new products and services is often linked with implementation of knowledge management systems (KMS) in virtual environments. Knowledge information may be explicitly represented (for example, in the form of rules, principles and structured information) or may be implicit (in the form of technical and cognitive skills transmitted with experiences of individual designers). Thus, the KMS has to comprehend knowledge information to transform implicit knowledge into accessible explicit knowledge that can be reused in relevant problem-solving situations. Since the Internet includes various types of structured information, it is difficult to build general-purpose knowledge taxonomy or ontology to manage all of the information. Rather the notion of a "shared context of knowing" [1] is to use for information management. One of prevalent approaches to this problem solution is the construction of "boundary objects" - such as classification schemes, cognitive maps and narrative structures [2].

In this paper, boundary objects are viewed as knowledge artefacts combined in some way into a single hierarchical network and supported by distributed designers themselves for own purposes. At the same time, knowledge artifacts are available for those who need it. The feature is that a shared context of knowing artefacts is established through creation of their FM-patterns, which can be multiple, and from which new knowledge structures can be composed automatically.

2. THE APPROACH PROPOSED

A main idea of the discussed approach corresponds to the view that understands information access and retrieval as a process of knowledge acquisition, in which designers through their interaction with information discover and internalise new knowledge [3]. Thereby, this approach does not require an achievement of a consensus about a common understanding the problem-solving situations among designers. On the contrary, it is aimed on a decentralised creation and maintenance of knowledge by supporting the personal patterns of interaction with information. These patterns are conceived as FM-patterns that reflect different interpretations of functional meaning and content of artifacts. The assumption is that they are to be selected to synthesize new FM-patterns which will visualize implicit knowledge of designers containing a shared context of knowing artifacts. Therefore a general goal is to infer new knowledge from combining the individual knowledge of distributed designers.

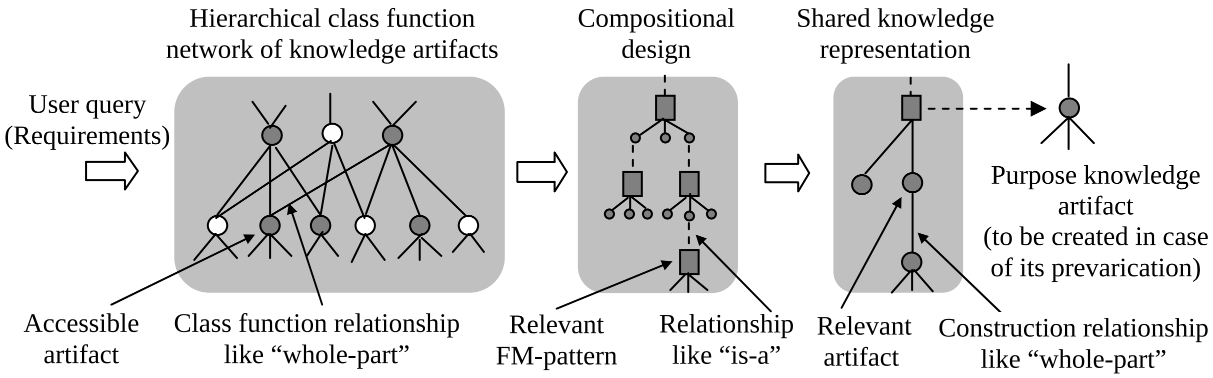


Figure1. A common scheme of compositional design

As shown on Fig.1 this approach is concerned with transforming the class functional hierarchical relationships between artifacts into construction hierarchical relationships between relevant artifacts through establishment of equivalence relationships like "is-a" between inputs and outputs of FM-patterns of these artifacts. For this end, two basic problems need to be solved:

- Development of cognitive class function templates enabling distributed designers to create FM-patterns of existent artifacts;
- Framing the problem of compositional synthesis based on multiple coupling artifacts.

3. CREATING FM-PATTERNS OF DESIGN ARTIFACTS

In this work, we concentrate on design artifacts, which are used to represent products as mechanical assemblies (level A), subassemblies (level S) and machine parts (level D). It is supposed that the design artifact includes not only the geometric description in form of drawing, sketch or CAD model, but also complementary information concerning function, behavior and structure captured in the process of creating FM-patterns of that artifact.

Primary information is represented by the division of all design functions into a finite set of classes interconnected with each other through "whole-part" relationships. The established hierarchical class function structure is then taken for the basis to interact and collaborate with destributed designers. Hence, the following definitions are arisen from:

- Cognitive template is two level branch of a general hierarchical structure consisting of some class function and all its subclass functions. It leads to specification of templates like (A-S), (S-D) and (D-C) types, where C denotes the lowest hierarchical level of functional decomposition related to class functions of machine part features [4]. Allowing the intersection of templates we thereby define a general hierarchical structure of collaborative design as network-based one.
- FM-pattern of design artifact is an instance of two level branch structure represented as a bipartite graph and described within a selected template in terms of instance functions, on the one hand, and in terms of design components, on the other hand. In order to create FM-pattern the designer has to identify only those instance functions and design components whose attributes exert influence on simulating behavior of artifact. Instance functions contain attributes that describe the function entities like power, force, material or signal. Design components contain attributes whose values are used to impose constraints on some key design dimensions, weight, physical volume, etc.
- Behavior specifies the response of an artifact to input conditions or behavioral states. From this point of view, any FM-pattern can be represented as a "black box", in which outputs are associated with a name of artifact and related instance purpose function, while inputs are associated with names of artifact components and related instance subfunctions. A common black box scheme of FM-pattern is shown on Fig.2, where the dotted lines denote internal relationships assigned with the designer to link together functional and design inputs and outputs. According to that representation, an artifact behavior depends on behaviors of its components

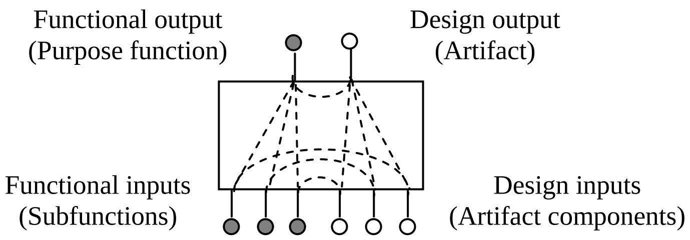
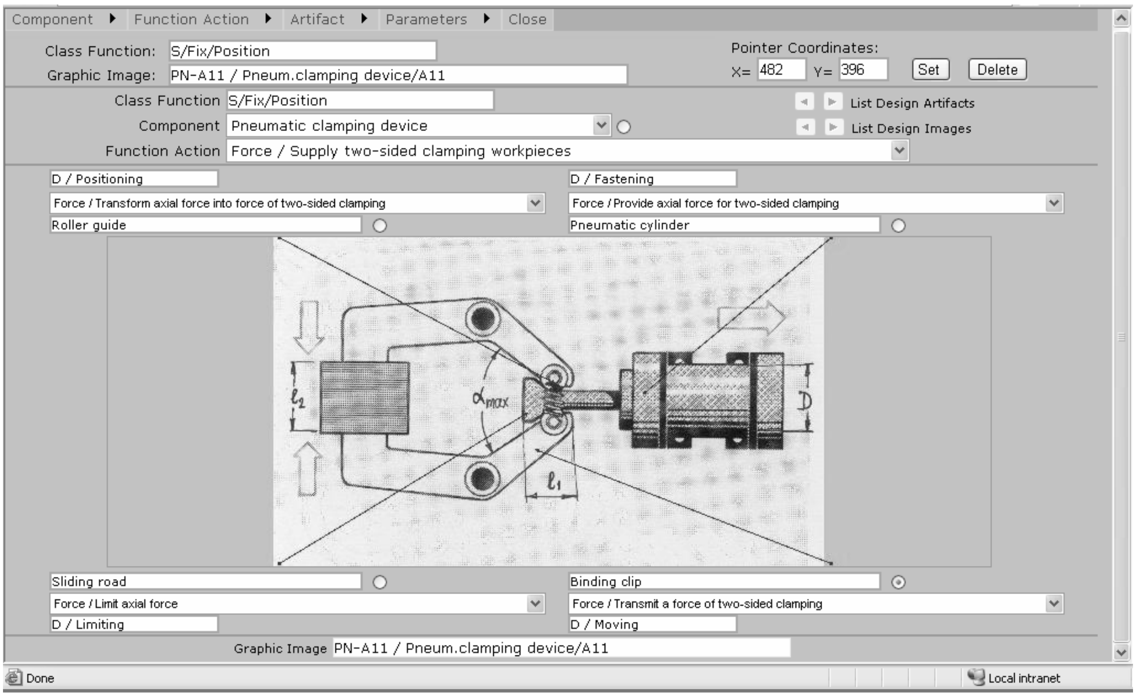


Figure 2. Black box representation scheme of FM-pattern

that is described in form of summarized parametric dependence (or computing algorithm) matching inputs with output of artifact.

Based on own purposes and perspectives designers can use different parametric dependences for describing an artifact behavior. Thus, they create multiple FM-patterns. Fig.3 shows a web-based interface to realise appropriate options including the application of pointers and comments in respect of instance functions and design components identified.



Class Function: S/Fix/Position
Graphic Image: PN-A11 / Pneum.clamping device/A11
Pointer Coordinates: X= 482 Y= 396
Class Function S/Fix/Position
Component Pneumatic clamping device ○
Function Action Force / Supply two-sided clamping workpieces

D / Positioning
Force / Transform axial force into force of two-sided clamping
Roller guide ○

D / Fastening
Force / Provide axial force for two-sided clamping
Pneumatic cylinder ○

Sliding road ○
Force / Limit axial force
D / Limiting

Binding clip ●
Force / Transmit a force of two-sided clamping
D / Moving

Graphic Image PN-A11 / Pneum.clamping device/A11

Figure 3.WEB-interface for creating multiple FM-paterns

4. COUPLING DESIGN ARTIFACTS

Following the method of compositional design we deal with the problem of both selecting and coupling relevant design artifacts to build a valid structure of function/means graph covering the user query (a set of functional requirements and design constraints). Formally, this problem can be considered as an extension of the purpose FM-pattern within (A-S), (S-D) or (D-C) hierarchical network levels. It means that the graph of an extended assembly unit can include only subassemblies and other assemblies, the graph of an extended subassembly can include only machine parts and other subassemblies, and the graph of an extended machine part can include only design features and other machine parts. A common algorithm of extended design is based on combining “top-down” and “bottom-up” composition stages as follows:

- Using the rules of functional coupling FM-patterns to create the shortest path of achieving the purpose function of design (top-down stage);
- Using the rules of behavioral coupling FM-patterns to provide valid correspondences between behaviors causing instance functions (bottom-up stage);
- Using the rules of design coupling FM-patterns to infer relevant purpose design artifact through design connectivity of its components (bottom-up stage).

At the first stage, a main coupling rule is compatibility of flows of power, force, material or signals in connection points (functional connectors) of FM-patterns. Two FM-patterns can be hierarchically connected provided that the functional output of subordinate FM-pattern is similar or coincides by its name, entity and some entity attributes (for example, power type is *mechanical*, power subtype is *rotational*) with one of vacant functional inputs of super FM-pattern. In this model, a maximal number of functional inputs in one FM-pattern cannot be more than four. Therefore, in a lack of vacant inputs, the next level of FM-patterns is used for generation of hierarchical relationships.

At the second stage, taking into account that the same instance function can be caused by different behaviors, the conditions of these functions fulfilment within the generated functional framework of the product are checked. For example, some function *Limit axial force of two-sided clamping* represented on Fig.3 is fulfilled in dependence on changing a length l_1 of design component *sliding road* ($C_{slid.road}$) concerned with moving a piston of *pneumatic cylinder*. It follows that behavior of that function can be symbolically described as $BC_{slid.road}(l_1)$. Thus, if subordinate and super FM-patterns are similar or coincide by their behaviors in the connection point then one can believe that instance function in this point is fulfilled correctly. Otherwise, it is necessary to select (or create) other subordinate FM-pattern for this connection point.

After a behavioral coupling FM-patterns, the design components of the product and relationships between them are defined automatically. For example, a behavior $BC_{slid.road}(l_1)$ elicits the design component $C_{slid.road}$. By analogy, other design components within the generated function/means structure of a product are determined. Therefore, at the third stage (which is performed simultaneously with the second stage), the main task is to match design components in design connection points so as their design parameters have met the given design constraints. Otherwise, it is necessary to select (or create) new visual images of artifacts for the same conditions of design coupling FM-patterns.

5. CONCLUSIONS

This paper presents a new version of general functional design methodology facilitated for application in Internet/Intranet environments. Allowing the notion of FM-pattern of design artifact and its description in form of black box scheme with a fixed number of connectors we have elaborated the way of multiple coupling FM-patterns to improve the quality of product structures generated. In order to generate optimal structures of products, it is necessary to weigh the relationships between FM-patterns. Therefore, the next work is the development of metaheuristic algorithms for solving optimisation problem on the basis of evaluating a relevance of design artifacts selected by conditions of designer queries

6. REFERENCES

[1] Swan, J. Knowledge Management in Action: Integreting Knowledge Across Communities. In Proceedings of 34th Annual Hawaii International Conference on SystemScience (HICSS-3), Maui, Hawaii, IEEE Computer Society Publications, 2000, p. 7017.

[2] Star, S. L. “The Structure of Ill-Structured Solutions: Boundary Objects and Heterogeneous Distributed Problem Solving” In Readings in Distributed Artificial Intelligence, Vol. II, San Mateo, CA: Morgan Kaufmann Publishers Inc., 1989,. pp 37-54.

[3] Novak, J., Wurst, M., Fleishmann, M., & Strass, W. Discovering, Visualizing and Sharing Knowledge through Personalized Learning Maps. In Proceedings of International Symposium “Agent-Mediated Knowledge Management”, Menlo Park, CA: AAAI Press, 2003, pp 101-108.

[4] Napalkov, E. Visual Knowledge Management System for Collaborative Conceptual Design, Proceedings of the 5th International Conference on Operational Research: Simulation and Optimisation in Business and Industry – SOBI2006, Tallinn, April 2006, pp 243-248.