SIMULATION OF ENGINEERING FEATURE BASED REASONING

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KEYWORDS

Mental Model, Cognitive Science, Creative Reasoning, Constructive Reasoning, Artificial Intelligence.

ABSTRACT

Presented paper deals with the simulation model build to verify applicability of feature based reasoning in conceptual design tasks. Feaure based model in the form presented herein in compare to frequently used object model brings the following advantages: comparability of features, easy implementation of analogical and metaphorical reasoning and also straightforward implementation of naive physic reasoning. The paper is focused to model structure and simulation tool description.

INTRODUCTION

There is no doubt about strong relation between creative (and constructive) problem solving and analogical and metaphorical reasoning, see (Hanard), (Plauen and Wilkening 1997) and (Visser 1996). In contradiction to classical AI this kind of reasoning is not undeniable based on strict form of the first or higher order logic; but it is build on subjective estimations of similarity (or on measures of satisfaction) of individual features and behaviours of reasoned objects. This is significant source of constructive and so-called creative reasoning variability - emergencies. The presented tool is build to help us to understand these processes and to understand why human designers don not reason in the terms of objects, inheritance, encapsulation.

MENTAL MODELS OF CONSTRUCTIVE REASONING

Presented mental model in the time of constructive task solving consists of
- Model of designed system
- Model of designed system operating environment
- Models of known systems, solutions, structures, processes, etc.

Model of designed system usually represented by multiple abstraction level model, see figure 1 and works (Brandejsky 2002,2003a). Each level is described by set of components (subsystems) and set of connections. There exist morphisms between levels. Multiple abstraction level model enables to describe top-down and bottom-up design processes.

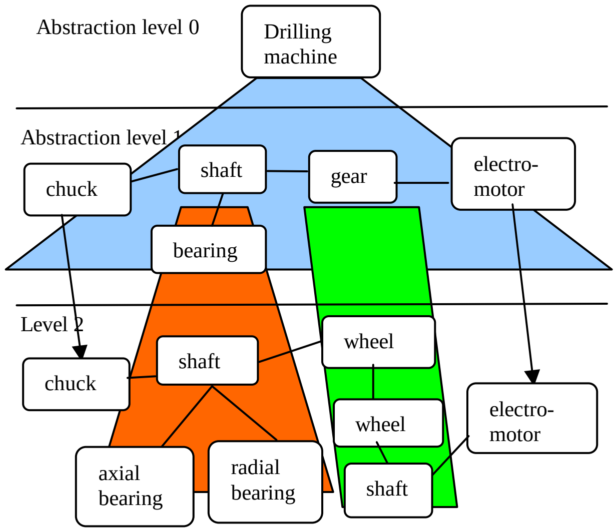

Figure 1: multiple abstraction level model representing drilling machine

Model of designed system operating environment determines a number of system parameters, behaviours and interactions with neighbourhood systems. These “commonsense” knowledge simplifies system requirements descriptions, makes them better understandable and fail-safe.

Models of known systems, solutions, structures and processes form knowledge base required for application of analogical and metaphorical reasoning in design process.

Analogical reasoning is based on application of reasoning rule:

IF A implies B and C has the same features as A
THEN C implies B

Figure 2: The analogy rule

The application of analogical reasoning depends on ability of the system:

1. to identify features of the objects
2. to measure similarity of the features
3. In the case of metaphorical reasoning we must add the following prerequisite:

Proceedings 21st European Conference on Modelling and Simulation
Ivan Zelinka, Zuzana Oplatková, Alessandra Orsoni ©ECMS 2007
ISBN 978-0-9553018-2-7 / ISBN 978-0-9553018-3-4 (CD)

4. to analyse structure of objects, if they are decomposable

Large discussion of analogical and metaphorical reasoning can be found e.g. in the work (Gentner et al. 2001). The main problem of analogical (and metaphorical) reasoning consists of the size of knowledge base. To be able to solve non-trivial problems, this base must be really huge. It is possible to speak about millions of objects, each of them described by tens and hundreds of features.

FEATURES DEFINED BY OBJECT REFERENCE

Management of knowledge-base for analogical reasoning simplifies if the features are separated from objects; it means if their semantic sense is independent on the object. This mechanism was hidden in original Minsky ideas, see (Minsky 1974) of the frame representation and enables to use analogical rules in easier way. But features in the Frame representation are understood as connection of related objects. In the presented model, the set of features defines the object, see (Brandejsky 2006). This step enables to free attributes from object. The definition of object attributes is given by the feature, object only instantiates them. For example, if the object has feature movement, it has such attributes as velocity or acceleration.

Presented simulation system is build with the goal to verify the applicability of description of semantic sense of features by set of references to neighbour hooding objects. In our model, in contrary to Object Oriented Programming, the description of features is separated from concrete object description and should be used by all objects implementing the feature. This fact eliminates the basic problem of OO modelling, the fact that features of objects are incomparable and offers description of their implementation, not the explicit expression of their semantic sense.

In the set of objects, it is possible to define features by many ways, e.g.:

1. by pinpointing of objects with the feature
2. by derivation from the set of known features
3. by references to sub-sets of neighbourhood objects

Naive physics and qualitative simulation use reference to neighbourhood objects with explicit description of features to derive of the system behaviours see e.g. (de Kleer and Brown 1984). For example structural features can be represent by relations to four class of objects:

1. encapsulated objects
2. object self-reference
3. objects on the identical abstraction level (neighbourhood objects)
4. superior object(s) determining environment

Such description brings advance in the possibility to use standard logical implication and quantifications. As an example it is possible to use model of drilling machine outlined at figure 1: Electric motor is the source of rotary moment (has the feature “source of rotary moment”). But there is physical law of action and reaction – the rotary moment influences not only the shaft but also the body of electromotor. There is also the condition of rotary moment rise – the input of electric energy. Thus the electro-motor is the source of rotary moment only if it is connected to at least one source of electric energy and to the one base eliminating reacting moment.

The main open problem of feature based reasoning is in the measurement and fusion of features and behaviours. The presented simulation system is developed with the aim to verify hypotheses and to establish suitable model. Problems are given not only by non-existence of measures of such features as shape elegancy but also by the limited additivity of known measures.

There are three basic methods of the work with fusion mechanisms:

1. it can be related to object
2. it can be common and influenced by related object(s)
3. or it can be common and attributes related to whole task, e.g. by emotions

The first version is difficult to manage – each object contains information about evaluation its feature set. It brings not only storage capacity problems but also difficulties if the new feature is discovered.

The second mechanism was presented e.g. in the work (Brandejsky 2003b) brings the problem with its recursive nature (measures determining if the object is analogical to the pattern are associated on the base of application of the another measures and fusion method).

The third method are probably the most related to the human reasoning. This method is not deterministic because its results depend on previous tasks solved by the system, because the successful solution of the task influences the methods of feature evaluation and fusion. The presented model is used to verify this hypothesis and to compare is with the other ones.

Relations between objects on the reasoned decomposition (abstraction) level are referring to objects features. They form so called schema. This schema is a part of superior object definition and it significantly influences superior object features fusion from the objects features.

FEATURE DESCRIPTION

Feature description consists of above mentioned description of semantic sense of the feature, set of variables representing feature attributes in concrete object instance, optional description of the feature fusion method and additional information like feature name. Feature descriptions are sometimes grouped into tree structure to represent situation when set of features is specialisation of more common one.

HYPOTHESIS FORMULATION

During the top-down design process designer decomposes system into the network of less complex parts. X of them are known (described in knowledge base), some of them are hypothetical and must be decomposed or detail designed in the future steps. Some features of these parts conclude from the system requirements and other components features. Then the features of hypothetical component must be carefully analysed to discover hidden requirements, e.g. in the case of source of rotary movement the input of any energy flow is asked. Thus, the hypothesis formulation block contains and uses base of basic physical knowledge.

ENGINEERING REASONING MODEL

Presented model uses both fusion mechanisms based on common mechanism and object class (domain) specific knowledge. The structure of the model is outlined at figure 2 and its structure připomíná expert systems, but the behaviours of the components are significantly different:

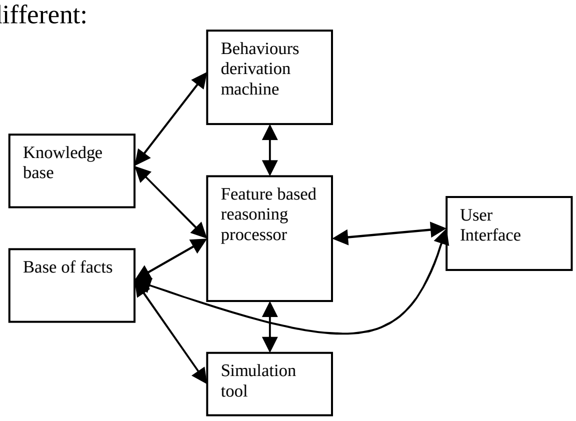

Figure 2: The structure of constructive reasoning simulation model

1. Knowledge base contains independent descriptions of features, as it is described above. It also contains description of object classes represented by set of features.
2. Base of facts stores the model of designed artefact and description of the task.
3. Feature based reasoning processor selects applicable objects from knowledge base on the base of their features, looks for analogies between searched solution and structures stored in the knowledge base or forms hypothetical components which will be concretised in the future design steps (top-down design).
4. Behaviours derivation machine is planned to simplify knowledge base design by automatisation of the knowledge based design.
5. Simulation tool module or interface is used to enable classical simulation to evaluate some design process steps when numerical attributes of features must be computed. It uses tools developed in the previous projects (Bila et al. 2006).
6. User interface is designed to support communication with the user.

ENGINEERING REASONING SIMULATION

Presented model is implemented in simulation environment called “Feature Based Reasoning Visual Studio”. The system consists of the following components: model browser, editor of features, editor of objects, editor of tasks descriptions and reasoning process viewer (used for communication during reasoning process and presentation of its results).

Simulation environment is used to buid related knowledge base. This knowledge base must be hudge to be applicable in non-trivial case problem solving. Unfortunatelly, it is impossible to demonstrate creative reasoning without large knowledge. The subject of the base is within the field of technical systems, especially mechanical, electrical and mechatronical. This focus is done not only by the previous knowledge of the author, but it is done also by the possibility to define attributes and measures in more precise way than e.g. in car body shape design. Reasoning process consists of basic design tasks solving like system structure definition, choose of relavant component or component substitution and component collision solving.

Simulation environment is shown at figure 4. In the future work, the new module of dynamic modification of features fusion on the base of successfully solved tasks evaluation will be added. This reasoning process will be used to verify if this mechanism is solving the problem of emergencies rising in the design process (also called unexpected discoveries).

It is difficult to compare presented architecture to another ones. E.g. well known works of Hofstadtter or Forbus do not reason about semantic sense of features.

Simulation results

The simulation of creative reasoning is not frequent. There it is need to verify carefully particular hypotheses but preparation of these experiments is time-consuming due to the need of large knowledge-base use and due to verification that the result of experiment “discovered solution” is not logically deducable from the knowledges and the experiment description. Our first result confirm hypotheses presented herein.

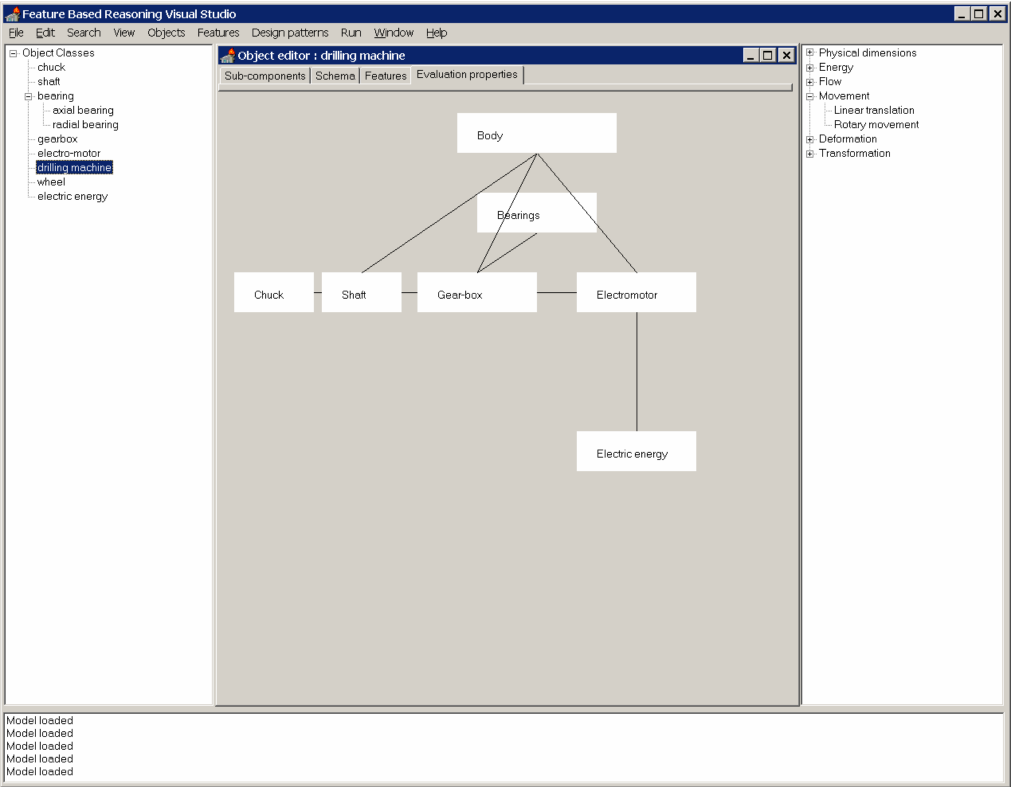

Figure 4: Reasoning simulation environment

Conclusion

The modelling of feature based human constructive reasoning is able to bring novel solution sin the fields of intelligent CAD and CASE systems and also to bring the large influence into the robotics research.

Acknowledgements

The work is solved within the frame of research project of Czech Ministry of Education No. MSM 6840770043.

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