THE GRAMMAR FOR THE DESCRIPTION OF ARTIFACTS IN THE CONCEPTUAL REDESIGN OF SYSTEMS

Jakub JURA and Jiri Bila

Department of Instrumentation and Control Engineering, Faculty of Mechanical Engineering, CTU Prague,
Technická 4, 166 07 Praha 6, Czech Republic
Fax : +420 2 3333 5603, Tel : +420 2 2435 2534
Jiri.Bila@fs.cvut.cz, Jakub.Jura@fs.cvut.cz

Abstract:*The paper deals with the grammar for generating and recognition of grammatically correct sign chains written in the ontology GLB (Global Context). The ontology GLB has been proposed for the specification and solution synthesis of a class of technical system. The ontology has 4 strata: The stratum of Fields of Activities (F_{Act}), Principles 1 (Princ1), Principles 2 (Princ2) and the stratum of diagrams (state and sequential diagrams) written in language UML. This paper follows-up our work on the interpretation of an ontology for Conceptual Redesign of Systems.*
The proposed grammar defines correct sign chains constructed in given ontology. The goal of this article is to support the development of the effective ontology for computer aided problem solving in conceptual design and redesign of systems.

Keywords: Ontology, Conceptual Design, Redesign, Field of Activities, UML (Unified Modelling Language).

1. Introduction

Computer support of design and redesign is very interesting and useful part of Problem Solving field in Artificial Intelligence. At this paper is described one approach to support of conceptual phase of design and redesign of a systems. The interest was shifted from formal means to semantic modelling and at this framework to effective description of functions of the designed systems. This shift allowed dealing with the conceptual phase of the design and redesign process more competently and to keep formal means of classical AI in the field of detailed design.

The ontology is the top of the semantic modelling which facilitate higher efficiency of semantic systems. There is mentioned grammar of the ontology GLB – Global Context. Ontology GLB is developed for redesign process – i.e., for improving known principles and systems. A user (designer) defines the current state and goals and computer generates suggestion to a new solution in the special form of Specification sign chains. The chains are then interpreted. Correctness and meaningfulness of this sign chain provides the grammar GLB grammar. Ontology GLB mediate relation between ontology and their user – designer.

2. The ontologies

The Gruber's definition of the term ontology is the most proximal to our conception from many more existing definitions. Gruber postulates the ontology as a **specification of the way of conceptualization that is used** [1], [2]. This definition was extended by Borst in 1997 (referred in [3]), which define ontology as a **formal specification of shared conceptualisation**. Conceptualisation is, in this context, system of the constructs that represents specific part of the world.
The ontologies are possible to discriminate according to object of formalisation to **domains** (deal with specific problem-field), **generic** ontologies (upper-level ontologies which deal with categories, general laws etc.), **task** ontologies (deal with processes of inference – no declarative, but procedural knowledge), **application** ontologies (specific ontologies for certain a application) and **representation** ontologies (that deal with representation primitives, paradigms, etc.). Ontology GLB is a domain and task oriented ontology.

2.1. Languages For Representation Of Ontologies

From the list of "older" semantic formalisms which can nowadays be considered as ontologies, we mention only Bylander's consolidations [4]. Consolidations are graphic-symbolic formations to describe functions on the level of principles. In combination with Suh's axiomatic theory of design [5], knowledge acquisition and knowledge representation were used to explain the system functions and for system design [6]. They are still used, e.g., in systems for automatic identification of functional structures, [7].

One of the most powerful means for representing ontologies is ONTOLINGUA [1], [2]. Its basic layer is done by KIF language (Knowledge Interchange Formate) [8], which is a variant of predicate first order language with the syntax of LISP.
Another languages for representation of ontologies are the following ones: OCML (Ontology Compositional Modelling Language), DAML-ONT (Darpa Agent Mark-Up Language-ONTology), OIL (Ontology Inference Layer) and DAML+OIL. Details, e.g., in [3].

3. The structure of the ontology GLB

The ontology that has been developed for conceptual redesign of machine, instruments and device components, now will be proposed.
The ontology denoted as a Global context (GLB) combines the features of **general semantic networks** and the features of **UML** language [9]. The ontology contains three basic strata (with their sub-strata):

- GLB_{Expl} - stratum of Explanation,
- GLB_{Fact} - stratum of Fields of Activities,
- GLB_{Env} - stratum of Environment.

Stratum Fields of Activities (GLB_{FAct}) has 4 sub-strata (Principles): GLB_{Princ1} (name of principles), GLB_{Princ2} (specification of the principles), GLB_{Princ3} (state UML diagrams dynamical network of a states and operations), GLB_{Princ4} (sequential UML diagrams).

A structure of strata and sub-strata is shown in Figure 1, which corresponds, to expression (1):

$$\boldsymbol{GLB} = \langle GLB_{Expl},\ GLB_{FAct}\langle GLB_{Princ1}\langle GLB_{Princ2} \langle GLB_{Princ3}, GLB_{Princ4}\rangle\rangle\rangle,\ GLB_{Env} \rangle, \qquad (1)$$

Strata and sub-strata GLB_{FAct}, GLB_{Princ1}, GLB_{Princ2} , have the structure of algebras.

$$GLB_p = \langle \boldsymbol{Fam_p}, \boldsymbol{F}\ (\boldsymbol{Fam_p}) \rangle, \qquad (2)$$

Strata and sub-strata GLB_{Expl}, GLB_{Princ3},GLB_{Princ4}, GLB_{Princ5} and GLB_{Env} have the structure of models.

$$GLB_p = \langle \boldsymbol{Fam_p}, \mathfrak{R}(\boldsymbol{Fam_p}) \rangle, \qquad (3)$$

where $\boldsymbol{Fam_p}$ are the ground sets (the carriers) of models and algebras, ($p \in$ {Expl, FAct, Princ1, Princ2, Princ3, Princ4, Princ5, Env}, $\boldsymbol{F}(\boldsymbol{Fam_p})$ are systems of operations and $\mathfrak{R}(\boldsymbol{Fam_p})$ are systems of relations introduced in ground sets $\boldsymbol{Fam_p}$. Ground sets $\boldsymbol{Fam_p}$ of models and algebras will in this paper be called „families“ (as in [1]) and their elements will be called “Formation Spaces ” (denoted as *FS*). (The set of all ***Fam***s is denoted as ***FAM***.)

Stratum Field of Activities (FAct):
Carrier $\boldsymbol{Fam_{FAct}}$ contains formation spaces of the fields of activities (E.g.: Mechanics, Pneumatics, Hydromechanics etc.).

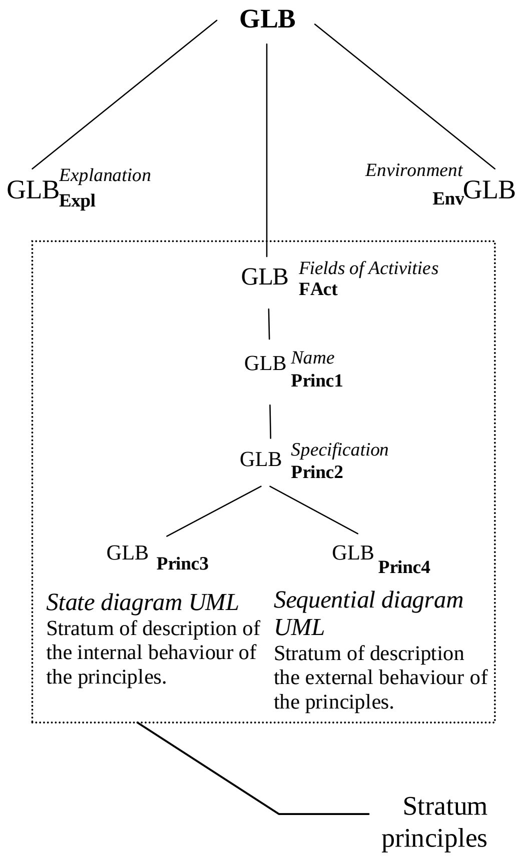

Figure 1*. A structure of strata and sub-strata of the ontology GLB.*

Stratum Principles 1 (Princ1):
Carrier FamPrinc1 contains formation spaces of the first layer of the principles (E.g.: Aggregation, Transformation, Relative Effects, Protection, Constructions etc.).

Stratum Principles 2 (Princ2):
Carrier $\boldsymbol{Fam}_{Princ2}$ contains formation spaces of the of the second layer of the principles (E.g.: Accumulation and Synthesis for first Principle Aggregation, or Joint, Filter and Bearing for principle Relative Effects etc.).

Strata Principles 3 (Princ3), Principles 4 (Princ4):
Carrier $\boldsymbol{Fam}_{Princ3}$ contains states and transitions of the UML state diagrams and Carrier $\boldsymbol{Fam}_{Princ4}$ contains objects, events and conditions of sequence diagrams both related to given ontology.

4. Ground sets of F_{Act}, F_{Princ1} and F_{Princ2}

Only illustrative fragments as examples of ground sets will be introduced in this section. The more detailed description is, e.g., in [10], [11], [12], [13], [14].

4.1. Ground set Fam_{Fact}

$\boldsymbol{Fam}_{FAct}$ = {**ME**, **PNU**, **HME**, **ELS, MSF, TCS, LGS, ORG, MAT, STRUCT…**}, (4)

ME … *Mechanics,*
PNU … *Pneumatics,*
HME … *HydroMechanics,*
ELS … *Electromagnetics and Electronics,*
MSF … *Mathematic, Symbolic and Formal,*
TCS … *Technological Constructions* (bridges, frames, boxes, join components, containers …),
LGS … *Legislation means* (conventions, decrees, imperatives),
ORG … *Organization* formation spaces,
MAT … *materials,*
STRUCT … *Structure* of components of a system (as a structure of interacting formation spaces).

4.2. Ground set Fam_{Princ1}

$\boldsymbol{Fam}_{Princ1}$ = {**Agg**, **Trns, Contr**, **Protc**, **Cnstr**, **R-Eff**, **Instr**, **Dam**, **Emb**, **Prod**}, (5)

Agg … *Aggregation,*
Trns … *Transformation,*
Contr … *Control,*
Protc … *Protection,*
Cnstr … *Constructions,*
R-Eff … *Relative Effects,*
Instr … *Instrumental,*
Dam … *Damage,*
Emb … *Embedding,*
Prod…*Production.*

4.3. Ground set Fam_{Princ2}

$\boldsymbol{Fam}_{Princ2}$ = {
Agg ⟨**Accum**, **Synth**⟩,
Trns⟨ **ChCarr**, **ChCarrV**, **Transfer**, **Transms**, **ChBeh**, **ChVVal**⟩**,**
Contr⟨ **Rep**, **Supp**, **Catal**, **Analog**, **Logic**, **F-Logic**⟩**,**
Protc⟨**ProtcProd**, **ProtcProp**, **ConsvState**⟩**,**
Cnstr⟨ **Separ**, **Fix**, **Bear**, **Content**, **Join, Shape, Milieu**⟩**,**
R-Eff⟨**Filter**, **Joint**, **Bearing**⟩,
Instr⟨**Tool**, **Material**, **Means** ⟩,
Dam⟨**Discard**, **Contamin, Destruct** ⟩,
Emb⟨**InConstr**, **Include**, **Annex** ⟩,
Prod⟨**Objects**, **UnivQual**, **UnivPower** ⟩
}, (6)

Accum … *Accumulation* (Aggregation without change of the aggregated components),
Synth … *Synthesis* (Aggregation with a change of the aggregated components),
ChCarr … *Change of Energy Carriers,*
ChCarrV … *Change of Carrier Variables,*
Transfer … *Change of position* of energy matter with possible changes of the internal properties,
Transms … (*Transmission*) Change of position of energy matter without changes of the internal properties,
ChBeh …. *Change of Behavior* of Energy matter,
ChVVal … *Change of Values* of descriptive Variables,
Rep … *Repression of an effect* (process, principle),
Supp … *Support of an effect* (process, principle),
Catal … *Catalysation* of an effect (process, principle),

Analog … *Analog control* of an effect (process, principle),
Logic … *Logic control* of an effect (process, principle),
F-Logic … *Fuzzy Logic* control of an effect (process, principle),
ProtcProd … *Protection of Products*,
ProtcProp … *Protection of Properties*,
ConsvState … *Conservation of a State*,
Separ ... *to Separate*,
Fix … *to Fix*,
Bear … *to Bear*,
Content … *to form* a volume,
Join … *to Join*,
Shape …*to Shape***,**
Milieu … *to form a Milieu*,
Filter … *Filter*,
Joint … *Joint*,
Bearing … generalized Bearing,
Tool … *Tool*,
Material … *Material*,
Means … *Means* (non special facilities to help an effect or action),
Discard … *to Discard* (to eliminate the existence),
Contamin … *to Contaminate*,
Destruct … *to Destruct*,
InConstr … *to embed* in a system and to use the functionality (of the embedded system or of both),
Include … *to embed without specified* utilisation of functionalities,
Annex … *to Annex*,
Objects … *production of Objects*,
UnivQual … *production of Universal Qualities* (money, water, light, foodstuffs),
UnivPower … *production of Universal Powers* (electrical energy, heat).

Note 4.3.1: The lists of Fields of Activities and Principles in the strata introduced above are considered open and here contain a transparent collection of ontological components.

4.4. Strata "Principles 3" (Princ3), "Principles 4" (Princ4)

Stratum ***"Princ3"*** contains UML state diagrams and stratum ***"Princ4"*** contains UML sequence diagrams**.**
For each line FAct – Princ1 – Princ2 there is at least one state or sequence diagram (according to need).
(In the final stage XML language is used to represent the diagrams from strata ***Princ3, Princ4***.)

5. Grammar of the ontology GLB

The grammar of ontology GLB is used for generating and recognition of grammatically correct sign chains (written in the ontology GLB). The proposed grammar consists of a *general grammar pattern* of sing chains and of a list of *forbidden grammar forms* (chains). The following illustration of the allowed and the forbidden sign chains (exactly meaningful and meaningless combinations of the given Fields of Activities, their Principles 1 and specifying Principles 2) is proposed at the common knowledge base in a meta-language (which is in this case natural language). Decision criterion of the admissibility of the sign chains are the meaningfulness and lucidity in the natural language.
The *general grammar pattern* of the sign chain has the form:

$$\begin{array}{llllllll}
\mathbf{Ch} & = & <F_{Act} & <\boldsymbol{\alpha}_1 & <\text{Princ1} & <\boldsymbol{\beta}_{11} & <\text{Princ2} & <\boldsymbol{\gamma}_{11}>>> \\
 & & & & \text{AND} & <\boldsymbol{\beta}_{21} & <\text{Princ2} & <\boldsymbol{\gamma}_{21}>>> \\
 & & & & \text{AND} & <\boldsymbol{\beta}_{i1} & <\text{Princ2} & <\boldsymbol{\gamma}_{i1}>>> \\
 & & & & > & & & \\
 & & & > & & & & \\
 & & \text{AND} & <\boldsymbol{\alpha}_2 & <\text{Princ1} & <\boldsymbol{\beta}_{12} & <\text{Princ2} & <\boldsymbol{\gamma}_{12}>>> \\
 & & & & \text{AND} & <\boldsymbol{\beta}_{22} & <\text{Princ2} & <\boldsymbol{\gamma}_{22}>>> \\
 & & & & \text{AND} & <\boldsymbol{\beta}_{j2} & <\text{Princ2} & <\boldsymbol{\gamma}_{j2}>>> \\
 & & & & > & & & \\
 & & & > & & & & \\
 & & \ldots & & & & & \\
 & & \text{AND} & <\boldsymbol{\alpha}_n & <\text{Princ1} & <\boldsymbol{\beta}_{1n} & <\text{Princ2} & <\boldsymbol{\gamma}_{1n}>>> \\
 & & & & \text{AND} & <\boldsymbol{\beta}_{2n} & <\text{Princ2} & <\boldsymbol{\gamma}_{2n}>>> \\
 & & & & \text{AND} & <\boldsymbol{\beta}_{kn} & <\text{Princ2} & <\boldsymbol{\gamma}_{kn}>>> \\
 & & & & > & & & \\
 & & & > & & & & \\
 & & >, & & & & &
\end{array} \qquad (7)$$

where $\boldsymbol{\alpha}_1, \boldsymbol{\alpha}_2, \ldots, \boldsymbol{\alpha}_n \in \boldsymbol{Fam}_{FAct}$, $\boldsymbol{\beta}_{11}, \boldsymbol{\beta}_{21}, \ldots, \boldsymbol{\beta}_{kn} \in \boldsymbol{Fam}_{Princ1}$, $\boldsymbol{\gamma}_{11}, \gamma_{21}, \ldots, \boldsymbol{\gamma}_{kn} \in \boldsymbol{Fam}_{Princ2}$, AND …is a connection operator with the meaning of logical AND, and "<", ">" and "," are sign separators.

The sign chains have simple structure as it is seen in the following examples:

- STRUCT(Agg(Synth) AND Trns(ChCarr)) AND TCS(Trns(ChCarr))
- ELS(Trns(ChCarr)) AND TCS(Trns(ChCarr))
- ELS(Trns(ChCarr)) AND TCS(Agg(Synth) AND Trns(ChCarr)).

A few examples of forbidden short sign chains are introduced in the following table.

Table of some forbidden sign chains

F_{Act}	*Princ1*	*Princ2*	*Description*	*Explanation*
MSF	R-Eff	**Bearing**	*Relative Effects - generalized Bearing.*	Currently it is not usual to implement the generalized Bearing by the mathematical formalism.
	Emb	**Include**	*Embedding - to embed without specified utilisation of functionalities*	Function and structure have the solid connection in math and there is not easy to embed something into a mathematical system and don't utilise this.
		Annex	*Embedding - to Annex.*	The operation to annex is not built in math formalism ordinarily.
	Prod	**UnivQual**	*Production of Universal Qualities (money, water, light, foodstuffs),*	Math and formal structures usually produce only math and formal structures.
		UnivPower	*Production of Universal Powers* (electrical energy, heat).	Math and formal structures usually produce only math and formal structures.
LGS	Trns	**ChCarr**	Transformation - Change of Energy Carriers.	Currently it is not usual to realise a change of energy carriers at the legislation field.
		ChCarrV	*Transformation - Change of Carrier Variables.*	Currently it is not usual to realise a change of energy carriers variables at the legislation field.
		Transms	*Transformation - (Transmission) Change of position of energy matter without changes of the internal properties.*	Currently it is not usual to realise a change of position of energy matter at the legislation field.
	R-Eff	**Bearing**	*Relative Effects - generalized Bearing.*	Currently it is not usual implement the generalised Bearing by the legislation means.
	Prod	**UnivQual**	*Production of Universal Qualities (money, water, light, foodstuffs),*	Although it is possible to describe production of the universal qualities by using legislation means, the legislation means don't produce universal qualities in itself.
		UnivPower	*Production of Universal Powers (electrical energy, heat).*	Although it is possible to describe production of the universal powers by using legislation means, the legislation means don't produce universal powers in itself.
ORG	Trns	**ChCarr**	*Transformation - Change of Energy Carriers.*	Currently it is not usual to realise a change of energy carriers at the organisation field.
	Cnstr	**-**	*Constructions principles (to Separate, to Fix, to Bear, to form a volume, to Join, to Shape, to form a Milieu)*	Construction principles are usually realised at the technical or physical field of activity.

Table 1. *An examples of forbidden short sign chains.*

The selection introduced forbidden sign chains have been correlated with a process of the interpretation [15] and with a process of semantic analysis of the connections of their components.

6. Conclusion

The development of ontologies is very demanded point of contact between informatics and engineering. The goal of this article is to support the development of an effective ontology for computer aided problem solving in conceptual design and redesign of systems.

7. Acknowledgments

This research has been supported by Research Grant MSM CR No. 2B06023.

8. References

[1] Gruber, T. R.: Translation Approach to Portable Ontology Specifications. *Knowledge Acquisition* Vol.5. No.2. (1993). pp. 199-220.

[2] Gruber, T.R. and Olsen, G.R.: An Ontology for Engineering mathematics. In: *4th Int. Conf. on Principles of Knowledge representation and Reasoning* (Doyle, J., Torasso, P. and Sandewall, E., Eds.). pp. 256-278. Morgan Kaufmann. Bonn (1994).

[3] Svátek, V. : Ontologie a WWW. In: *Sborník z konference Datacon*. http://www.cogsci.princeton.edu/~wn. (2002).

[4] Bylander, T, and Chandrasekaran, B.: Generic tasks in Knowledge-based Reasoning: The Right Level of Abstraction for Knowledge Acquisition. In: *Knowledge Acquisition Based Systems* (Gaines, B.R. and Boose, J.H., Eds.). Vol. 1 (1988). pp. 65-77. London. Academic Press.

[5] Suh, N.P.: *The Principles of Design*. Oxford. University Press. (1990).

[6] Katai, O., Kawakami, H., Sawaragi, T., Konishi, T. and Iwai, S.: Method of Extracting Meta Plan for Designing from Artefacts Analysis Based on Axiomatic Design Theory. *Transactions of the Society of Instrument and Control Engineers*. Vol. 31 (1995). No.3. pp. 347-356.

[7] Kitamura, Yo.,Toshinobu, S., Namba, K. and Mizoguchi, R.: A Functional Concept Ontology and its Application to Automatic Identification of Functional Structures. *Advanced Engineering Informatics*, Vol. 16 (2002). No.2. pp. 145 – 163.

[8] Michael, R. G.: Knowledge Interchange Format, In: *Proc. of 2nd Int. Conf. on Principles of Knowledge representation and Reasoning* (Fikes, R., Allen, J. A. and Sandewall, E., Eds.). pp. 599-600. Cambridge. MA. (1991).

[9] Rumbaugh, J., Jacobson, I. and Booch, G.: *The Unified Modelling Language Reference Manual*. Addison-Wesley (1998).

[10] Bíla, J. and Tlapák, M.: Knowledge Discoveries and Emergent Synthesis in Conceptual ReDesign Process. In: *Proc. of Int. Conf. on Comp. Intel. Modeling, Contr. and Automation - CIMCA' 2005*, (Mohammadian, M.- editor), CS IEEE, Vienna, (2005) pp. 537-543.

[11] Bíla, J. and Tlapák, M.: Ontologies and Formation Spaces for Conceptual ReDesign of Systems. *AED'04*, Glasgow, (2004) CD ROM, E2, 1-8.

[12] Bíla, J., Tlapák, M. and Jura., J.: Emergent Synthesis in Conceptual ReDesign Process. In: *Proc. The 6th International Workshop on Emergent Synthesis – IWES 06*, August, Kashiwa, Japan (2006), CD ROM.

[13] Bíla, J. and Jura, J.: Artificial Intelligence and Emergent Synthesis in Conceptual ReDesign Process. In: *Proc. of 5th Int. Workshop on Soft Computing Applied in computer and economic environments – ICSC 2007*, European Polytechnical Institute in Kunovice, January, (2007), pp. 289-296.

[14] Bíla, J. and Tlapák, M.: Ontologies for the Conceptual ReDesign of Systems. In: *Proc. of 10th Int. Conf. on Soft Computing - MENDEL 2005*, červen, Brno, (2005), pp. 120-125.

[15] Jura, J. and Bila, J.: The Interpretation Of The Ontology For The Conceptual Redesign Of Systems. In: *Proc. of 16 th Int. Conference on Process Control*. High Tatras, Slovakia (2007).