FACTA UNIVERSITATIS
Series: **Mechanical Engineering** Vol. 11, N° 2, 2013, pp. 181 - 192

INTERPRETING THE MEANING OF GEOMETRIC FEATURES BASED ON THE SIMILARITIES BETWEEN ASSOCIATIONS OF SEMANTIC NETWORK

UDC 004.8

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Abstract *In this paper the method of semantic network analysis which enables semantic network data categorization is presented. The main goal of the network analysis is determination of the similarity of the semantic network associations based on their attribute values. The method allows highly efficient semantic categorization of new concepts, which does not depend on pre-planned inputs and predefined inference rules. Also, the method allows different semantic interpretations of the same concept in different semantic contexts. As a specific example for demonstration of the semantic categorization process, a part of mold manufacturing workflow is chosen.*

Key Words: *Artificial Intelligence, Semantic Features, Cognitive Data Processing, Active Semantic Model, Manufacturing*

1. INTRODUCTION

The semantic categorization as a term from cognitive psychology is used to express the process of assigning meaning to a (new) item [1, 2]. With the semantic data models, this process is usually performed by setting up a semantic relation between the concepts (nodes) in the semantic network. Semantic categorization represents one of the biggest challenges faced by modern information technologies. Computer networking in the Internet has enabled an instant access to huge amounts of data and information. However, it is often rather difficult to find appropriate information, namely the one for which the user

Received December 3, 2013

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Acknowledgements. This paper is part of the project "The research of modern non-conventional technologies application in manufacturing companies with the aim of increase efficiency of use, product quality, reduce of costs and save energy and materials" (project id TR35034), funded by the Ministry of Education, Science and Technological Development of Republic of Serbia.

searches. The information access quality does not equally follow increases of available information [3]. Research in cognitive psychology suggest that the process of searching information contents should include the search of meaning (or according to the meaning) of what is required in order to conduct it in a significantly more precise and even faster way [4, 5]. Following these recommendations, the current research trend in the field of information technologies includes two main subdirections which complement each other: a) research and creation of semantic data models and b) research and modeling of cognitive processes.

A large piece of knowledge is already embedded into modern Computer Aided Product Development (CAPD) systems. Actually, parts of mathematics, physics, chemistry, and other fundamental sciences are turned into algorithms as well as programming code of these systems. On the other side, tacit knowledge [6] with its origin in experience and intuition as well as its liability to permanent updating and changes through a direct touch with the product development process, is often very difficult to turn into strongly defined algorithms. This kind of knowledge has stayed, more or less, out of CAPD systems. Nevertheless, it plays a crucial role in making important assessments, judgments, inferences and decisions. The tacit knowledge products have a huge impact on the strategic product development process features. Exploration of the methods for embedding and using tacit knowledge is an important and unavoidable evolutionary step forward in the CAPD systems development and, certainly, one of the greatest challenges in the field of IT application in the product development process.

In this paper an approach is described where a new semantic model named Active Semantic Model (ASM) is used for modeling and semantic interpretation of geometry elements in a CAD model. The ASM structure and the method are explained and demonstrated in a given case. The focus is on the method description.

2. Active Semantic Model

ASM [7] is a new semantic model which has been developed in-house. Its primary aim is to capture and interpret semantics of the design features related to manufacturability issues [8]. ASM intends to introduce an alternative approach to knowledge representation in comparison with the existing semantic models by moving the focus of data structuring from concepts to semantic relations or associations (the term which is used in ASM). This idea of structuring the meaning in associations is chosen to support the thesis stating that the knowledge that people have about items (visual representations, objects, situations, etc.) is contained in inter-concept associations that abstractly represent those items [9]. Furthermore, ASM has proved itself as a more flexible and productive in capturing and interpreting semantics of data compared to the existing semantic models [7]. Here, we explain an algorithm for determining the similarity of associations as a core process in determining semantic inter-concept similarity.

2.1 Structure

The ASM structure consists of: *Concepts*, *Associations* between concepts, Concept *bodies*, and *Contexts*.

ASM *concepts* are at the same time nodes of the ASM semantic network and abstract representations of objects, features, situations, etc. The concept data structure consists of only one parameter – *Name*. Concept *bodies* are their realizations.

The ASM association structure is characterized by eleven parameters [7]: *name*s ($\boldsymbol{cpt_i}$, $\boldsymbol{cpt_j}$) of two concepts (or contexts) that are associated (network nodes are part of association); topological parameters: *roles* ($\boldsymbol{r_i}$, $\boldsymbol{r_j}$) of concepts (i.e. type, subtype), *type* ($\boldsymbol{t}$) of associating (i.e. classifying), *direction* ($\boldsymbol{d}$) of associating (←, ↔, →) and *character* ($\boldsymbol{c}$) of associating (+, -); weight parameters: *accuracy* ($\boldsymbol{h}$) of associating for given context (0; 0.25; 0.5; 0.75; 1) and *significance* ($\boldsymbol{s}$) of associating for given context (0; 0.25; 0.5; 0.75; 1); and affiliation parameters: *context* id to which an association belongs, and *user* id to identify who has created the association. There can be only one concept with given name, but there can be many associations belonging to different contexts associating it with other concepts. *Type* of association states the relationship between the two concepts, i.e. the *role* of each concept in the association. In this way the values for parameters *roles* of concepts and *type* of association are coupled and can be considered as ordered triplets.

ASM also introduces *contexts* which are sets of semantically close associations. The context brings abstract meaning of a certain object, situation or event, and, therefore, it is semantically designated. *General context* is defined and built into ASM structure independently of the user. As for others, *particular contexts* require additional semantic description by the user. All the associations from particular contexts are assigned (usually with different parameters) to the general one. *Association plexus* in ASM is, in general, a context subset (mathematical structure) and can be considered without specific abstract meaning. This difference between association plexus and the context has no effect on data processing and their use for the data semantic interpretation in ASM.

The ASM structure is not domain-specific and can be used for knowledge representation in diverse fields. The knowledge from specific domain should be represented through context(s). Semantic relations between contexts allow knowledge from one context to be applicable to others.

3. INTERPRETING THE SEMANTICS OF DATA IN ASM

Cognitive data processing (CDP) algorithms represent a set of data processing procedures with which ASM attempts to perform data semantic interpretation. They enable ASM to acquire new knowledge independently and make meaningful decisions and responses. This group of algorithms consists of:

1. the procedure of determining:
   a. the class of similarity of associations, and,
   b. the degree of semantic similarity of concepts
2. the algorithm for Determining the Similarity of Associations (DSA) (the core of this algorithm is the procedure for Determining the Parameters of Association (DPA))
3. the algorithm for Determining the Similarity of Contexts (DSC)
4. the algorithm or the Procedure of Contexts Upgrading (CUP)
5. the algorithm for the creation of heuristics and knowledge "crystallization."

3.1. Procedure for determining association parameters

Determination of semantic similarity of two concepts is usually performed for the concepts which are not directly connected by associations (CPT_X and CPT_N), i.e. in the cases when there exists at least one layer of concepts between CPT_X and CPT_N known to ASM (layer of "connectional" concepts CPT_i (Fig. 1)) through which they are connected. Pairs of associations through which concepts CPT_X and CPT_N are connected to the same connectional concepts CPT_i are called common associations (Fig. 1). The process of determining semantic similarity of two concepts results in the creation of association(s) between these two concepts. The parameters (type, direction, character, accuracy, and significance) of this (these) association(s) are determined through the procedure of determining association parameters. Concepts CPT_X and CPT_N which are directly connected with one or more associations (Fig. 1) are already semantically categorized. However, determination of semantic similarity for these concepts is possible and needed after every modification of semantic network (after the creation of new associations).

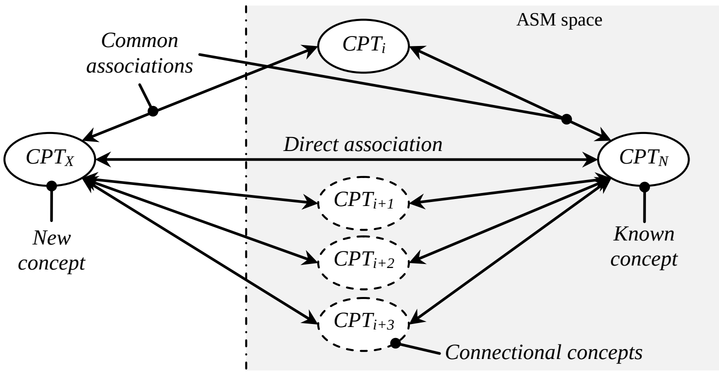

Fig. 1 Schema of semantic relations and concepts with illustration of used terminology

The association parameters values, and, therefore, the semantic features of a new concept, generally depend on the set of parameter values of all the association pairs. The associations parameters also depend to a large extent on the contexts containing these associations and semantic elements (concepts and contexts) connected by them. In other words, two concepts can be in completely or partially different semantic relations, depending on the context wherein they are observed. The characteristic of each association in terms of its belonging to a certain context implicitly connects that context with members of this association (concepts or contexts that are connected by this association). This implicit connection between association members and context to which this association belongs is determined by the values of association parameters that are appropriate for given context (Fig. 2).

Therefore, it can be stated that the association parameters values, and, consequently, the new concept's semantic features in the given context, depend on the set of parameter values of all the association pairs that belong to that context.

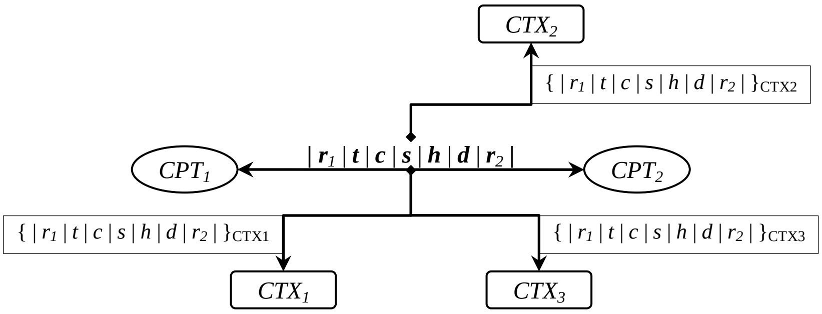

Fig. 2 Connection between semantic relations (associations) and sets of semantically close associations (contexts)

In order to take into account the influence of accuracy and significance of associations, as well as relevance of associations in accordance with context, ASM, in all the cases, determines the values of the association parameters between concepts CPT_X and CPT_N as follows:

1. ASM determines parameters of association for general context (CTX_0):
   a. ASM separates a subset of accurate and significant associations of general context. All association pairs that belong to general context whose product of arithmetic mean values of accuracy and significance is smaller than 0.25 are excluded from further process of determining the association parameters values.
   b. ASM performs the procedure of determining the values of parameters of association according to the established algorithm (which will be described in detail later in this section).
   c. ASM creates association between concepts CPT_X and CPT_N with the determined values of association parameters.
2. ASM determines parameters of association for every particular context (CTX_S) which includes associations and concepts connected by them:
   a. In the first step of refinement for every particular context, ASM takes into account the whole set of associations by which concepts CPT_X and CPT_N are connected, including associations that are excluded in previous step. ASM excludes pairs of associations in which associations belong to different contexts. Furthermore, ASM excludes a subset of association pairs in which associations belong to the general context, but keeps their variations in particular contexts. At the end of this step, only association pairs in which both associations belong to the same particular context and association pairs in which associations belong only to general context are kept.
   b. ASM groups pairs of associations according to specific context. For every subset, grouped according to specific context, ASM selects a subset of accurate and significant association pairs. All association pairs that belong to specific context whose product of arithmetic mean values of accuracy and significance is smaller than 0.25 are excluded from further process of determining the association parameters values.

c. ASM performs the procedure of determining the values of parameters of associations according to the established algorithm for every subset of association pairs.
d. ASM creates associations between concepts CPT_X and CPT_N with determined values of association parameters for every specific context separately.

3.1.1 The procedure of determining the type of association

There are three characteristic cases that determine what type will be assigned to the association created during the categorization:

1. ASM determines complete match of all parameters of all association pairs (fifth class of similarity). In this case ASM creates an association of "synonymous" type between these two concepts (CPT_X is synonym for CPT_N).
2. ASM determines that new concept CPT_X and known concept CPT_N have associations of at least the same type toward connectional concepts CPT_i. In other words, these associations can be of the same or different character, direction, accuracy and significance. Therefore, similarity of at least first class is achieved. In this case ASM creates association of "similarity" type between these two concepts (CPT_X is similar to CPT_N) (Fig. 3).

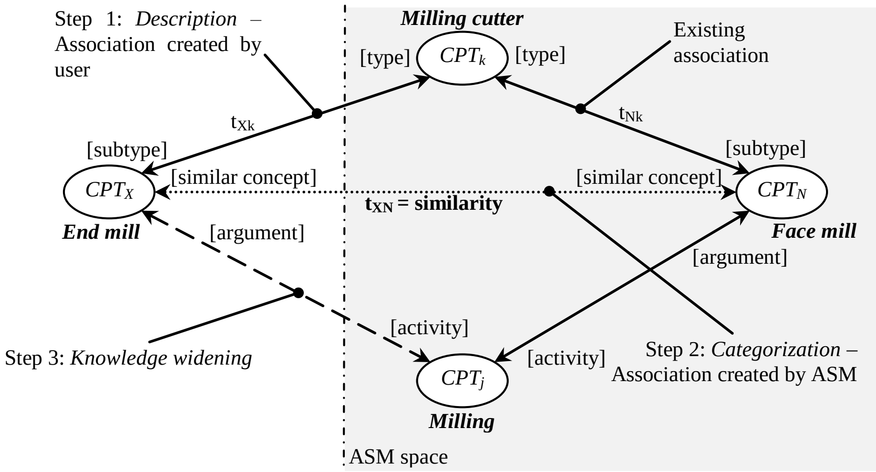

Fig. 3 Determination of the type of association for the case of the second, third or fourth class of similarity

3. ASM determines that concepts CPT_X and CPT_N share associations of zero class of similarity with concepts CPT_i. Hence, in this case, concepts CPT_X and CPT_N have associations of different types with the same (connectional) concepts CPT_i, i.e. roles of concepts CPT_X and CPT_N in these associations are different. The type of association that will connect concepts CPT_X and CPT_N will be determined depending on the class of association plexus in which new concept CPT_X is found. For example, an easily recognizable class of association plexus is the one that de-

scribes some activity (Fig. 4). In this kind of plexus, besides the concept that represents the activity itself, there exists motive for performing that activity, activity subject or subjects (who is performing the activity), activity object or objects (against which the activity is performed), activity argument (with which the activity is performed), product, and result of activity. Therefore, it is sufficient to introduce part of association plexus to enable ASM to recognize the class of association plexus for the description of activity. In the next step ASM starts directed search procedure over the semantic network in order do determine the rest of the associations from the plexus. This procedure is intended for pre-planned types of plexuses (association plexuses that describe activity, assembly, etc.). This procedure is based on the CASE algorithm which contains explicitly defined causal mechanism (rule) for every pre-planned CASE.

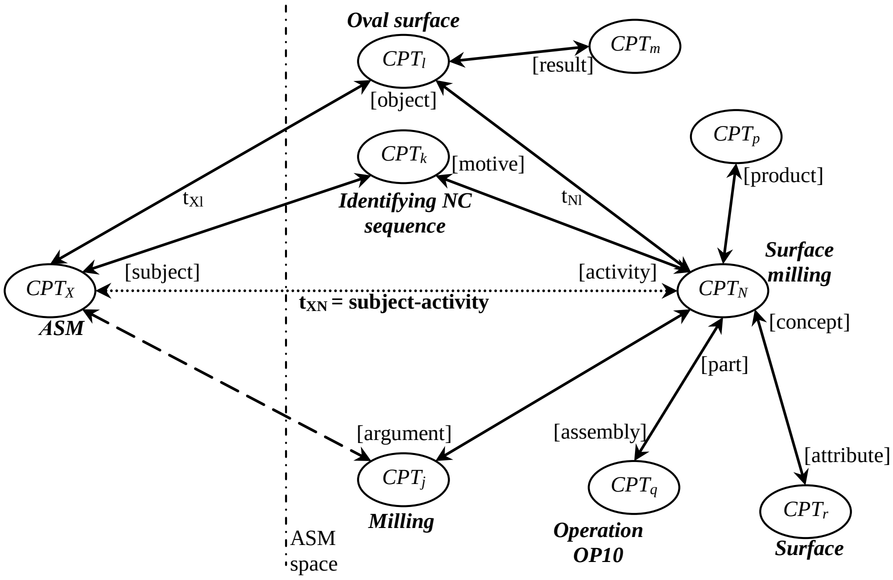

Fig. 4 Association plexus describing the activity "Surface milling"

3.1.2 The procedure of determining accuracy and significance of association

The values for accuracy and significance of the association being created between concepts CPT_X and CPT_N are determined according to the following equations:

$$s_{xn} = 1 - \frac{\sum_{i=1}^{k} |s_{Xi} - s_{Ni}|}{k} \quad (1)$$

$$h_{xn} = 1 - \frac{\sum_{i=1}^{k} |h_{Xi} - h_{Ni}|}{k} \quad (2)$$

where k is the number of association pairs formed between concepts CPT_X and CPT_N and the same concepts CPT_i from the semantic network.

Since association accuracy and significance take values from a finite set of standard values (0; 0,25; 0,5; 0,75; 1) for the sake of simplicity, it is necessary (though not required) to adopt values for these parameters that will be different from the calculated values. These values are adopted as follows:

Table 1 Adopting the values for accuracy and significance of association

Conditional part	Result
$s_{xn} \geq 0.5$	s_{xn} = first bigger standard value
$s_{xn} < 0.5$	s_{xn} = first smaller standard value
$h_{xn} \geq 0.5$	h_{xn} = first bigger standard value
$s_{xn} < 0.5$	h_{xn} = first smaller standard value
$s_{xn} = 0$ or $h_{xn} = 0$	Remove $A_{cptx \leftrightarrow cptn}$

3.1.3 The procedure of determining the character of association

Determination of the association character, in the case when there is only one association pair between concepts CPT_X and CPT_N, is carried out using the following matrix (which is illustrated in Fig. 5):

Table 2 Matrix for determining the character of association (only one association pair)

c_{Xk}	c_{Nk}	c_{XN}
+	+	+
+	–	–
–	–	+
–	+	–

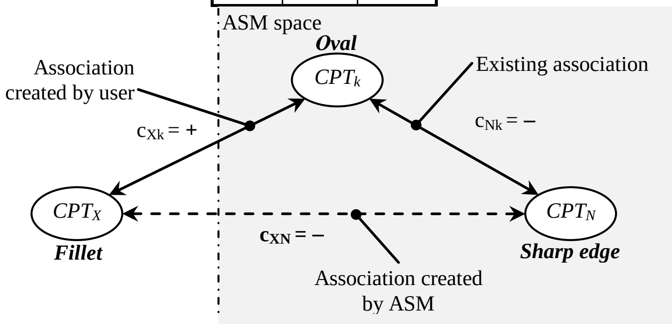

Fig. 5 Typical schema of associations during the determination of association character (only one association pair)

In the case when there are multiple association pairs (and, consequently, more connectional concepts) between concepts CPT_X and CPT_N, the function for determination of the character of association which should be created between concepts CPT_X and CPT_N varies depending on the case:

1. When there are multiple association pairs between concepts CPT_X and CPT_N which have the same characters. In this case ASM creates association of positive character between concepts CPT_X and CPT_N. Concepts CPT_X and CPT_N associate the same connectional concepts CPT_i in the same way – affirmative or nonaffirmative.
2. When there are multiple association pairs between concepts CPT_X and CPT_N which have different characters. In this case ASM creates association of negative character between concepts CPT_X and CPT_N. If all association pairs have the same types, then ASM creates the association of negative character and "antonymous" type.

3.1.4 The procedure of determining the direction of association

Determination of the association direction in the case when there is only one association pair between concepts CPT_X and CPT_N is carried out using the following matrix (which is illustrated in Fig. 6):

Table 3 Matrix for determining the direction of association (only one association pair)

d_{Xk}	d_{Nk}	d_{XN}
→	→	→
→	←	↔
→	↔	→
←	→	↔
←	←	←
←	↔	←
↔	→	→
↔	←	←
↔	↔	↔

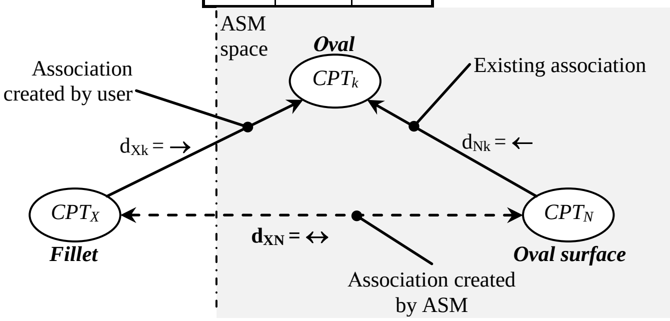

Fig. 6 Typical schema of association during the determination of association direction (only one association pair)

In the case when there are multiple association pairs (and, consequently, more connectional concepts) between concepts CPT_X and CPT_N the function for determination of the direction of association which should be created between concepts CPT_X and CPT_N is also defined according to the matrix:

Table 4 Matrix for determining the direction of association (multiple association pairs)

d_{X1}	d_{1N}	d_{X2}	d_{2N}	d_{X3}	d_{3N}	d_{XN}
→	→	←	→	→	←	→
→	←	←	→	→	←	↔
→	↔	…	…	…	…	…
←	→	…	…	…	…	…

4. CASE

A simplified example of the mold manufacturing workflow will be used for the demonstration of the approach. Instead of usual mold cooling canals, the tool constructor has planned conformal cooling canals. The usual mold cooling canals are straight, have a circular cross section, and are manufactured by drilling (deep drilling). The conformal cooling canals extend on a spatial curve (trajectory), and usually have a circular cross section. By following the form of lateral ribs, the conformal cooling canals can approach certain parts of the mold and provide a more complete air outlet. However, the conformal cooling canals, because of their shape, can not be manufactured by drilling. Therefore, the regular technological process, which implies manufacturing of cooling canals by drilling, cannot be performed. Thus, an exception related to the mold geometry causes disturbance of manufacturing process workflow, preventing the regular technological process. The scenario that shows the ASM application in this situation is the following:

The ASM semantic network already contains a semantic description of the following concepts: opening, hole, canal, cooling canal, straight line, curve, trajectory, circular cross section, drilling, etc. Some concepts are part of the "mold" context, while the others belong to the general context. During the introduction of the concept "Spatial curve" DPA algorithms will (by using the CASE algorithm presented in Fig. 7) connect concepts "Spatial curve" and "Straight line" with the "subtype-type" association, whose character will be harmonized with the character of the association between concepts "Curve" and "Straight line" (negative character). This means that these two concepts are associated nonaffirmative, i.e. one excludes the other. The next association pair that will be processed by DPA algorithms is "Spatial curve"↔"Straight line"↔"Axis". This pair will induce ASM to conclude that "Spatial curve" and "Axis" are similar, but again with negative character. In the last iteration of reasoning ASM will connect concept "Spatial curve" with concept "Drilling" modeled on the association between concepts "Axis" and "Drilling" with the association of negative character (Fig. 8).

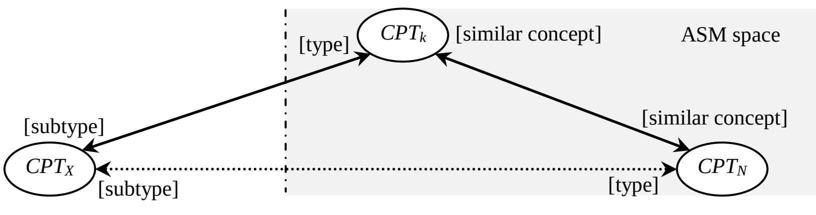

Fig. 7 The schema of decision making for the case with one "similarity" type association

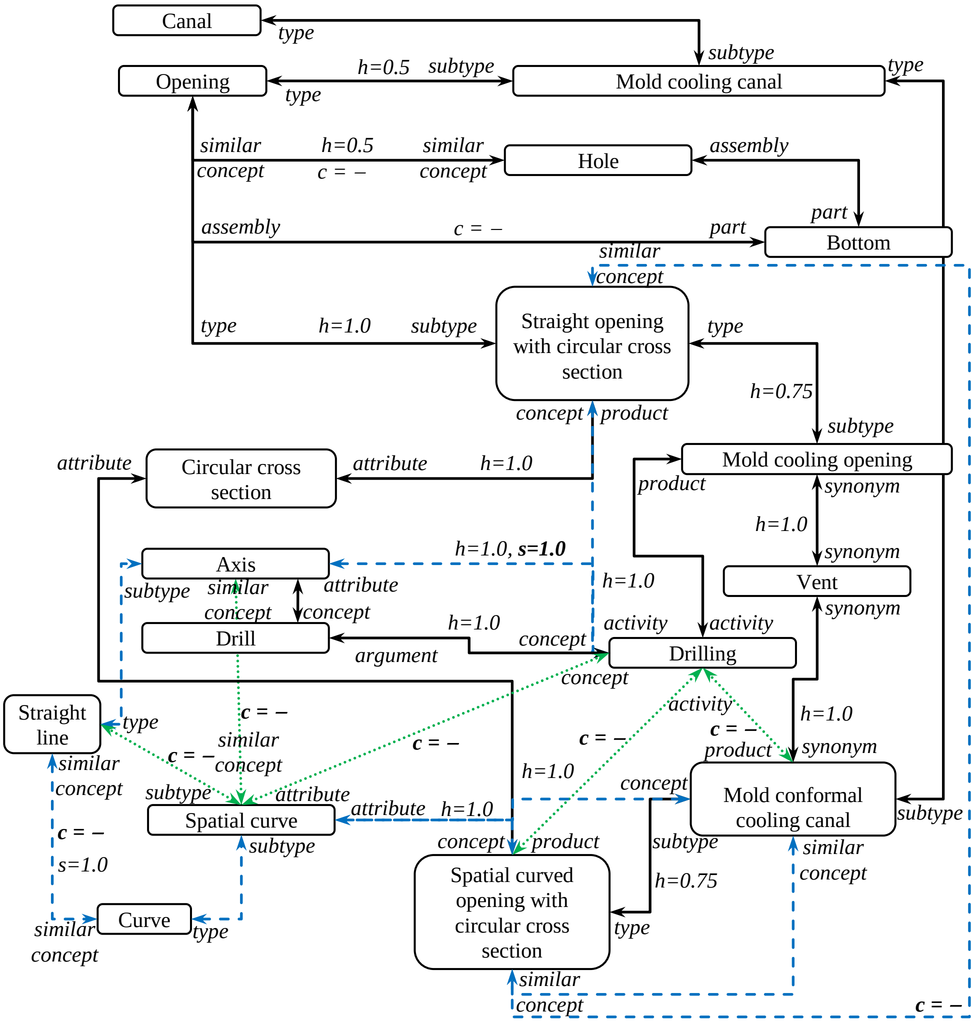

Fig. 8 Part of the ASM semantic network representing geometric and technological features of the mold cooling canal. Green associations are added based on the analysis of blue associations

In the following reasoning iterations, negative character of the association between concepts "Spatial curved opening with circular cross section" and "Straight opening with circular cross section" will be reflected, in a similar way, on semantic relation between the concepts "Spatial curved opening with circular cross section" and "Drilling". Finally, negative character of the association between concepts "Spatial curved opening with circular cross section" and "Drilling" will be reflected on semantic relation between the concepts "Mold conformal cooling canals" and "Drilling" (Fig. 8).

5. CONCLUSION

Active Semantic Model (and its procedures of cognitive data processing) have succeeded in carrying out the first three steps of semantic interpretation autonomously:

1. Introduction – by the initial associating of a new set of data with the data that exist in the semantic network of ASM,
2. Recognition – by determining of similarity of associations between the new and the known elements of the ASM's semantic network,
3. Categorization – by generating associations between the new and the known elements of the ASM's semantic network,

The developed functionalities of ASM provide for new possibilities for the autonomous generation of relatively precise and useful assessments and predictions in the beforehand unpredicted or insufficiently precise defined input data sets.

REFERENCES

1. Deutch, J. A., Deutch, D. , 1963, *Attention: Some Theoretical Considerations*, Psychological Review, 70, 80-90.
2. Norman, D. A., 1968, *Toward a theory of memory and attention*, Psychological Review, 75, 522-536.
3. Krill P., 2000, *Overcoming Information Overload*, InfoWorld.
4. Peterson, L.R., Peterson, M.J., Miller, G.A., 1961, *Short term retention and meaningfulness*, Canadian Journal of Psychology, 15, 143-147.
5. Kostić, A., 2006, *Kognitivna psihologija*, Zavod za udžbenike i nastavna sredstva, Beograd.
6. Nonaka, I., Takeuchi, H., 1995, *The knowledge creating company: how Japanese companies create the dynamics of innovation*, Oxford University Press, New York.
7. Stojkovic, M., Manic, M., Trifunovic, M., Misic, D., 2011, *Semantic categorization of data by determining the similarities of associations of the semantic network*, E-Society Journal Research and Applications, 2, 3-13.
8. Stojkovic, M., 2011, *Analysis of the Manufacturability Parameters Based on Semantic Structures of the Digital Product Model*, PhD Thesis, University of Nis, Faculty of Mechanical Engineering in Nis, Nis, Serbia.
9. Anderson, J.R., Bower, G. H., 1973, *Human Associative Memory*, Winston, Washington, DC.

INTERPRETACIJA ZNAČENJA GEOMETRIJSKIH ODLIKA BAZIRANA NA SLIČNOSTI ASOCIJACIJA SEMANTIČKE MREŽE

U radu je predstavljen koncept analize semantičke mreže koji omogućava semantičku kategorizaciju podataka. Glavni cilj analize je utvrđivanje sličnosti asocijacija semantičke mreže na osnovu sličnosti vrednosti atributa asocijacija. Koncept omogućava efikasnu semantičku kategorizaciju novih pojmova, koja ne zavisi od unapred planiranih ulaza i definisanih pravila zaključivanja. Pristup omogućava i različite semantičke interpretacije istog pojma u različitim semantičkim kontekstima. Kao primer za demonstraciju procesa semantičke kategorizacije je iskorišćen deo radnog toka izrade kalupa.

Ključne reči: *veštačka inteligencija, semantičke odlike, kognitivna obrada podataka, Aktivni semantički model, izrada*