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Synthesis of the Physical Principle of Operation of Engineering Systems in the Software Environment CPN Tools

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Abstract: Among the most promising approaches to the implementation of the initial stages of designing of the new high-performance engineering systems there is a method related to the involvement of the structured physical knowledge in the form of physical effects. The physical effects are used for automated synthesis and selection of the physical principle of operation of the engineering system designed. One of the major issues acting as a brake on the efficient and wide implementation of this method is the task of assessment of the practical implementability of the synthesized structures. In the study, we have presented the analysis of approaches to the evaluation of the synthesized structures of the physical principle of operation of the engineering systems on the basis of use of the graph theory and the mathematical tools Petri nets. The developed algorithms embedded in the automation of synthesis of the physical operating principle in the CPN Tools Software environment allow evaluating the set of the generated POP chains in the context of the practical implementability thereof.

Key words: Physical effect, physical operating principle, petri nets, initial stages, engineering systems

INTRODUCTION

At the present time one of the major tasks is the design of the new high-performance engineering systems (TS). There is a number of approaches to the implementation of the initial stages of the TS design the most promising amongst which is the approach related to the involvement of the structured physical knowledge in the form of Physical Effects (PE) (Fomenkov *et al*., 2013; Korobkin *et al*., 2013a; Zaboleeva-Zotova *et al*., 2013; Kravets *et al*., 2014) for automated definition and selection of the Physical Operating Principle (POP) of the TS being developed.

The analysis of the studies related to the application of physical effects at the initial stages of the TS design has revealed a number of issues inhibiting the efficient and wide implementation of these methods (Fomenkov *et al*., 2014; Korobkin *et al*., 2013b, c, 2014; Korobkin and Fomenkov, 2009, 2011) including the problem of evaluation of the synthesized structures, i.e., methods of determining the physical implementability thereof.

PROCEDURE

We understand under a physical operating principle (Fomenkov *et al*., 2013) a structure of the compatible and united PE ensuring translation of the specified input actions (-s) into the specified output one provided that the two tandem PE $W_i = (A_i, B_i, C_i)$ and $W_{i+1} = (A_{i+1}, A_{i+1}, C_{i+1})$ are considered to be compatible with regard to the reference model of the PE description if the output action of a particular PE C_i of the POP chain is equivalent to the input action of the next PE A_{i+1}, i.e.:

- The output C_i pattern matches the input A_{i+1} pattern
- The name of the output C_i matches the name of the input A_{i+1}
- The qualitative characteristics of the output C_i match the qualitative characteristics of the input A_{i+1}. Matching is achieved by means of imposition of the AND-OR tree of the input action on the AND-OR tree of the output action
- If the output C_i and the input A_{i+1} are parametric then the physical quantities describing C_i and A_{i+1} match

The listed conditions of compatibility of the input and output actions are implemented in the form of rules for comparison of the output C_i encoding vector with the input A_{i+1} encoding vector.

Further, the next rule for determining the PE compatibility is used: if (i+1) PE has a few inputs (A^s_{i+1}) the output C_i is aligned with any of the A^s_{i+1} inputs satisfying the condition of equivalence to C_i.

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The issue of the implementability evaluation is proposed to be solved by means of constructing a set of criteria based on the POP structures. It is necessary to introduce the additional PE field a criterion representing the practical implementability of the relevant PE. On the basis of this attribute the PE weight factors will be assigned. In such case the task of selection of the most optimal POP is reduced to the combinatorial optimization task (measurement of the total weight of the POP obtained). Within this study we proceed from the assumption that the weights are obtained and their discrete values are used for selection of the optimal POP chain from among the available POP set. The input data of the method of synthesizing the linear POP structures:

- The length of the POP synthesis chain4
- Criteria of the initial action A_1 and criteria of the resultant action C_k

In order to select the most optimal POP chain from the entire set of the chains obtained it is proposed to use the following algorithm. If we know the weights w_i of each PE representing the relevant practical implementability of the PE then the task of selection of the most optimal POP chain is reduced to solving the problem of finding the shortest path on the weighted graph. The problem of finding the shortest path or the traveling salesman problem has a lot of the solution algorithms many of which are implemented in the different software packages. However, these algorithms have a shortcoming in respect of the problem set. Let's assume that there are two POP chains connecting the specified input and output of the same weight. The question arises: How to determine which of the POP chains is the most optimal one? Let's consider the POP chain with the minimum of nodes to be the most optimal one. In order to select the most optimal POP chain from the two or more equally weighted and with the equal number of chain nodes let's introduce the uniformity concept. The weight of the POP chain:

$$w(y) = \sum_{i=1}^{n-1} w(v_i, v_{i+1}) \quad (1)$$

where, $<v_1, v_2, ... v_n>$ is the sequence of nodes in the POP chain. Let's consider the arithmetic mean value of the weighting factors for each edge of the shortest path found:

$$A(y) = \frac{\sum_{i=1}^{n-1} w(v_i, v_{i+1})}{n} \quad (2)$$

Let's calculate the difference between the weighting factors and arithmetic mean value:

$$R(y) = \sum_{i=1}^{n-1} w(v_i) - A(y) \quad (3)$$

Let's add the sum of the values obtained. Let us call this sum the uniformity coefficient. Thus, by choosing between the two POP of the same length and weight we will take into account this uniformity coefficient. The lesser the uniformity coefficient is the more optimal is the calculated shortest path (POP):

$$\text{if } R(y) < R(POP_{min}) \text{ then } POP_{min} = y \quad (4)$$

where, POP_{min} is the most optimal POP chain.

SYNTHESIS OF THE PHYSICAL OPERATING PRINCIPLE BY MEANS OF A PETRI NET

The model of synthesis of the physical operating principle represents a colored Petri net. This Petri net is designed on the basis of the already existing model of PE description (Fomenkov *et al*., 2013; Korobkin *et al*., 2013) as well as on the PE compatibility concept and algorithm of synthesis of the physical operating principle.

A physical effect is represented by a complex type phe consisting of the input and output action (voz), qualitative characteristics of the input and output actions (kachv), physical effect number (numfe), physical quantities (vozf), weight of the physical effect (weight). The plist field represents a list in this pattern it is used for storage of the PE numbers entered in the POP chain. At the output of this software model we obtain a set of markers being the PE that complete the POP chain. Each of these markers travels of the way of synthesis from the initial stage and to the exit from the model and contains at each simulation stage the information about the current (added) PE to the POP chain as well as the list of all physical effects used in this POP structure. Descriptions of the color sets used in the software model in the CPN Tools environment are represented in Fig. 1.

The model of the POP synthesis on the basis of the Petri nets is represented in Fig. 2. The elements of the designed model are the submodel Synthesis, transition p selecting from the entire set of the markers (PE) the input POP markers, transition check length checking the synthesis process stopping conditions.

The synthesis model is a hierarchical model which means the nested construct: net inside of a net. The substitution of the synthesis transition is represented by a box with a double border line. Transition of the high-level network synthesis is logically substituted by the similar network of a lower level.

Positions of the low-level network that are used for connection with the high-level networks are called ports

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▼colset voz = with voz1|voz2|voz3|voz4|voz5|voz6|voz7|voz8|voz9|voz10|voz11|voz12|voz13;
▼colset vozf = with fizvel1|fizvel2|fizvel3|fizvel4;
▼colset kachv= with vrem1|vrem2|vrem3;
▼colset napr = with vnutr|vnesh|vnutVnesh;
▼colset spec= with spec1|spec2|spec3|spec4|spec5|spec6|spec7;
▼colset pros = with proc1|proc2|proc3|proc4|proc5|proc6|proc7|proc8;
▼colset numfe = INT;
▼colset plist = list INT;
▼colset weight = INT;
▼colset phe = product voz*kachv*vozf*voz*kachv*vozf*numfe*weight*plist;
```

Fig. 1: Descriptions of the color sets

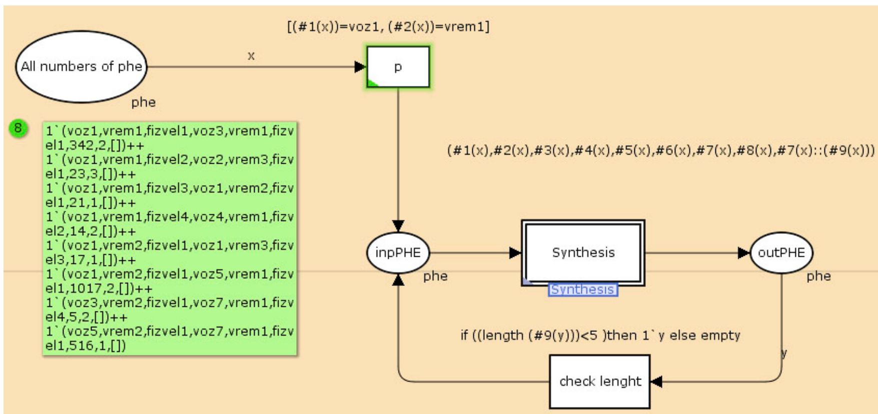

Fig. 2: Hierarchical model of POP synthesis

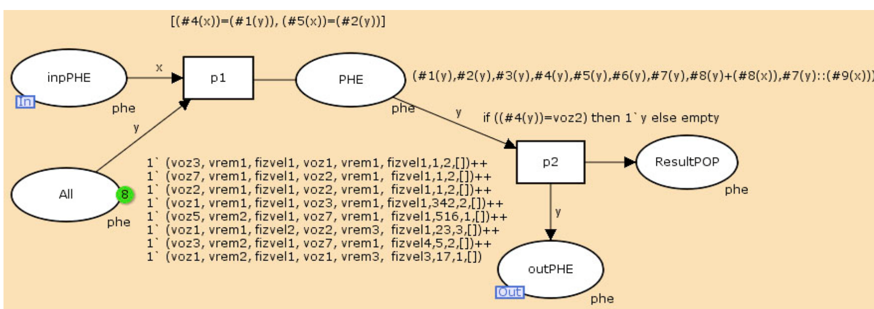

Fig. 3: Subnet synthesis

and are marked with special tags (I/O, In, Out). The corresponding positions of the high-level networks are called sockets. In this case, sockets are the positions inpPHE and outPHE in Fig. 2 and ports are inpPHE and outPHE on the page synthesis (Fig. 3).

The "p" transition features its functions only if the first field of the marker from the position all numbers of phe corresponds to the specified input action of the target POP. Thus, in the position inpPHE we have a set of markers (PE set) the input action of which matches the input actions of the target POP, i.e., these PE may be the initial ones in the POP chain.

The formula of the output arc of the p transition represents a constructor for generation of new tokens. In this case, it changes the last field of the marker the number of the current PE is entered in it since further on the marker will be changed and will represent the next element (following the PE in the PE chain). The transformations history, i.e., the entire chain up to the current element is stored in the field plist of the marker.

From among the entire set of markers of the All position only those markers representing the entire PE set in respect of which the following condition is fulfilled are transferred to the transition p1 (Fig. 3). The input action of the marker transferred shall equal to the output action of the marker from the position "inpPHE". Thus, at this stage the (i+1)th PE is attached to the ith PE. The weight of all PEs in a POP is summarized and stored in 0 "weight" and the entire chain up to the current element is stored in the field plist.

The transition condition p2 is the condition of exiting the POP synthesis process. The position "ResultPOP" includes the markers the range of the output action of which is equal to the output action of the target POP chain. Such markers represent the Final Element (FE) of the POP chain, all fields of such marker contain information about the last closing element of POP, the field weight contains the value of the weight of the entire POP chain in the field "plist" the numbers of "All Pes" of the relevant POP chain are specified. In the position "outPHE" all markers that do not meet the specified condition, i.e., incomplete chains are placed and returned to the inpPHE position for continuation of the search.

DISCUSSION

The application of the approaches presented in this paper as to evaluation of the synthesized structures of the physical principle of operation of the engineering systems on the basis of use of the graph theory and the mathematical tools of Petri nets has shown the increase in the designer performance as compared to the use of the existing systems of the POP synthesis due to ignoring the knowingly unrealizable POP designs.

CONCLUSION

There has been developed the model of evaluation and synthesis of the POP designs on the basis of the mathematical tools of Petri nets. The algorithm of evaluation of the synthesized structures of the physical operating principle on the basis of the graph theory has been designed.

The algorithms presented in the study that were embedded in the program of synthesis of the physical operating principle in the CPN Tools Software environment allow evaluating the set of the generated POP chains in the context of the practical implementability thereof.

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REFERENCES

Fomenkov, S.A., D. Korobkin and S. Kolesnikov, 2014. Method of ontology-based extraction of physical effect description from Russian text. Proceedings of the 11th Joint Conference on Knowledge-Based Software Engineering, September 17-20, 2014, Volgograd, Russia, pp: 321-330.

Fomenkov, S.A., S.G. Kolesnikov and D.M. Korobkin, 2013. Formation and structure of the physical effects databases. J. Volgograd State Tech. Univ., 18: 153-157.

Korobkin, D.M, S.A. Fomenkov and S. Kolesnikov, 2014. Ontology-based extraction of physical effect description from Russian text. Proceedings of the European Conference on Data Mining and International Conferences on Intelligent Systems and Agents and Theory and Practice in Modern Computing, July 15-17, 2014, Lisbon, Portugal, pp: 260-262.

Korobkin, D.M. and S.A. Fomenkov, 2009. The model of representation of the structured subject-related information in the form of physical effects in the text in the natural Russian language. Bull. Comput. Inform. Technol., 7: 17-21.

Korobkin, D.M. and S.A. Fomenkov, 2011. Automated procedure of retrieval of the structured physical knowledge in the form of physical effects from the texts in the natural English language. J. Volgograd State Tech. Univ., 3: 116-120.

Korobkin, D.M., S.A. Fomenkov, S.G. Kolesnikov and Y.F. Voronin, 2013a. System of physical effects extraction from natural language text in the internet. World Applied Sci. J. (Inform. Technol. Mod. Ind. Edu. Soc.), 24: 55-61.

Korobkin, D.M., S.A. Fomenkov and S. Kolesnikov, 2013b. Semantic network of physical effects descriptions in natural language context. Proceedings of the IADIS International Conference on the WWW/Internet, October 22-25, 2013, Fort Worth, TX., USA., pp: 342-346.

Korobkin, D.M., S.A. Fomenkov, S.G. Kolesnikov and Y.A. Orlova, 2013c. A multi-stage algorithm for text documents filtering based on physical knowledge. World Applied Sci. J. (Inform. Technol. Mod. Ind. Educat. Soc.), 24: 91-97.

Kravets, A.G., S.A. Fomenkov and A.D. Kravets, 2014. Component-based approach to multi-agent system generation. Proceedings of the 11th Joint Conference Knowledge-Based Software Engineering, September 17-20, 2014, Volgograd, Russia, pp: 483-490.

Zaboleeva-Zotova, A.V., Y.A. Orlova, V.L. Rozaliev, S.A. Fomenkov and A.B. Petrovskij, 2013. Formalization of inital stage of designing multi-component software. Proceedings of the IADIS International Conference Intelligent Systems and Agents, July 23-26, 2013, Prague, Czech Republic, pp: 107-111.