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SUPPORT SYSTEMS FOR DECISION AND NEGOTIATION PROCESSES

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REPRESENTATION OF DECISION MAKING PROCESSES FOR THE ECOLOGICAL EVALUATION SYSTEM

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ABSTRACT: The article deals with the problems of knowledge acquisition, structurization and representation in the decision support system directed to the dynamically changing environment. The approach of representing static and dynamic aspects of the enterprise system and reflecting them on the deep knowledge representation level, uniting with different decision making mechanisms provided by different specialist-experts, is proposed. The results of modelling are demonstrated by the examples developed during the designing stages of the object ecological evaluation system.

KEYWORDS: decision support system (DSS), deep knowledge representation, dynamic modelling, temporal aspects, E-nets.

1.Introduction

Our universe of discourse is concerned with decision making which is aimed at the ecological evaluation of objects (industrial, agricultural and the like) that contaminate territorial waters and air. The decision making is aimed at the permission for further exploitation or building new objects, that pollute or can potentially contaminate surroundings, and is related with the problems of estimation of a general ecological situation in the given region, all indices of pollution provided in the project, risk factors related with the preservation of links, that have biological significance dependent on time. Decision making is performed considering a lot of various factors, evaluating the monitoring data, comparing reports and real situation, etc..

The questions of analysis and uniting of different decision making mechanisms,provided by various specialists, into the common model of the same DSS have a direct relation with the problems of choosing and applying the means to knowledge acquisition, structurization, representation and formalization of reasoning . The orientation towards model-based rule learning approaches of knowledge acquisition is caused by the qualitative and deep representation of knowledge provided by a semantic model allows to represent the domain specificity more expressively and to choose the main, firstly used principles and rules. This deductive approach bypasses an ordinary and multiple modelling which is used to obtain the rules from the examples. It also enables us to deduce the mechanism of operative decision making more efficiently.

The existence of polysemantic knowledge requires the use of several methods for knowledge representation in the same system. It is possible to detect the knowledge formed by the contextual domain investigation modes. This is the level of conceptual representation of entities, processes, situations by concepts (basic elements) of the domain. The problem of specification of statical and dynamical aspects has arisen and it has been discussed by many authors during the recent decade. The actual contribution to modelling of statical and dynamical aspects of information and to proposing conceptual schemes was made by Brodie and Silva. (1982), Casanova et al.(1983), Rolland (1984), Bussolati et al.(1983). Modelling is considered to be a complex and important process especially in the first phases of the system development if we orient towards modelling support tools as it is presented by Wijers et al. (1991). Information modelling is that part of the requirements engineering which has to deal with interaction, incompleteness and heuristic, etc.

Another level is the representation of expert empirical knowledge provided by the practical experience and the actions of leading specialists of the domain. At the stage of creating a model of decision making processes there arise the questions of rule control and connection of the output mechanism with temporal attributes. The problem of rule specification lies in the fact that the behavior models of the person making a decision are not complete, the context rules are specific, sometimes contradictory. The rule control is simplified when the knowledge units in separate rules are arranged into the larger and more generalized ones. If the manipulation with larger spaces of search and application of several lines of reasoning are taken into account, then the number of causal rules using the abstract spaces of search in respect of general knowledge increases. The representation of rules and their dynamic control is based on the extension of Petri nets, called evaluation nets (E-nets) described by Noe and Nutt (1973). The E-net notation is extended by some temporal parameters by Dzemydienė (1986, 1988), Dzemydienė and Baskas (1990) is used to represent the dynamics with respect to explicit temporal aspects of the enterprise system at different levels of representation. The temporal knowledge representation aspects are of primary interest in the DSS context when the problems of retrospective analysis and prognosis are considered. A variety of temporal representation approaches for specifying events in the DSS context are proposed such as historical models by Clifford and Warren (1983), Ariav (1986); date line models by Kahn and Gorry (1977), Gustafsson et al. (1988), Gadia et al. (1988); the models represented as before/after chains by Kahn and Gorry (1977), Hennessy et al. (1985); interval based models by Allen (1983), De et al. (1987). It is not easy to efficiently represent the temporal knowledge by using a single representation scheme but we sought to suggest the notation allowing to represent different aspects of temporal knowledge by using common formalisation means.

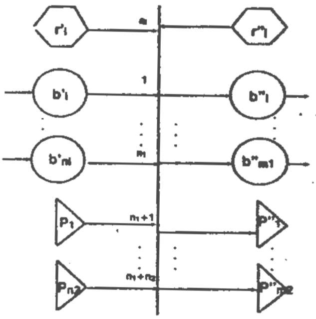
2. *Extension of the E-net notation to represent the dynamics with explicit temporal aspects.*

An E-net as represented by Noe and Nut (1973) is a connected set of locations over the set of allowable transition schema, and the net is denoted as the following four-tuple $E=(L,P,R,A)$. We consider the net as the relation of (E, M_0, ξ, Q, Ψ), where L is a finite, nonempty set of locations $\{b_j\}$; P is the set of peripheral locations $\{p'_j, p''_j\}$, where $\{p'_j\}$ are input peripheral locations and $\{p''_j\}$ are output peripheral locations; R is the set of resolution locations $\{r'_i, r''_i\}$; A is the finite, nonempty set of transition declarations $\{a_i\}$; M_0 is the initial marking of the net; ξ is the set of token parameters; Q is the set of transition procedures $\{q'_i\}$, Ψ is the set of procedures of resolution locations $\{\psi(r'_i), \psi(r''_i)\}$. An E-net transition was denoted by Noe and Nutt (1973) as $a_i=(s,t(a_i),q_i)$, where s is a transition schema, $t(a_i)$ is transition time and q_i is a transition procedure. To represent temporal aspects, a transition description is extended as follows:

$a_i = (L', L'', r'_i, r''_i, t'_f, t(a_i), t'_f \pi t_i, q_i, \{\xi'_j\}, \{\xi''_j\}, \psi(r'_i, r''_i), st_i\}$,

where i is an index of transition, L' is the set of input locations $\{b'_j\}$ of the transition, where $j=\overrightarrow{1,n}$, n is the number of input locations, L" is the set of output locations $\{b''_j\}$ of the transition, where $j=\overrightarrow{1,m}$, m is the number of output locations; $L', L'' \in L$; r'_i is the location of complex conditions for input of the transition (i.e. resolution location); r''_i is the resolution location for output of the transition; $t'_p(i)$ is the planned moment of transition firing, $t'_p(i) \in T^*$, where $T^* = T \cup \{t^*\}$, T is an absolute time scale, $\{t^*\}$ are time moments determined approximately (i.e. not fixed beforehand); $t'_f(i)$ is the factual moment of transition firing; $t(a_i)$ is the duration of the transition work; t_i is periodical transition time; $q_i \in Q$ is a procedure, which realizes a reflection of $M \times \xi' \times L' \times L'' \times T^* \times R$ to ξ'' according to the rules of transition work and determines the tokens $m \in M$ flow with parameters $\{\xi'\}$ from input locations $\{b'_j\}$ to output locations, taking into account the functions of resolution procedures $\psi(r'_i)$, $\psi(r''_i)$ at the actual time moment t'_f. t'_f at the current time moment is equated to real time moment from the absolute time scale $t_c \in T$. st_i is the specification of temporal relationships of the transition with other marked time moments.

A general view of the transition schema is shown in picture 2.1.



Pic.2.1. A general view of the extended E-net transition schema.

3. The knowledge acquisition and structurization for the representation in the DSS.

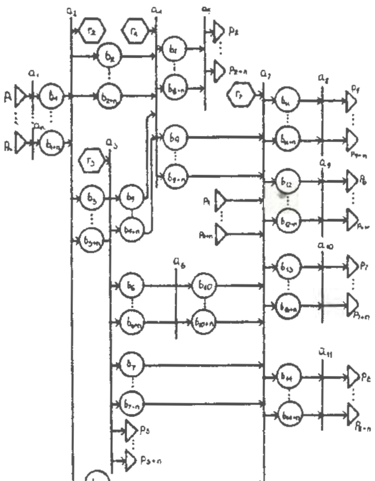
Three levels of representation: deep knowledge, analyzed enterprise system behavior and decision making processes are distinguished in this system. The system is devoted to the specialists of ecology to evaluate the activities of objects related with pollution.

A semantic submodel of static components is constructed by using three types of abstractions between the chosen entities (aggregation, generalization and transformation) described by Kangassalo (1983,1984). This is the scheme of „workspace" of the working memory. The necessary information involved in the submodel for the soiling level evaluation is the following: the usage of materials and natural resources in the process of production of the object, throwing out of harmful materials into the air, throwing out of harmful materials into the territorial waters, utilization of waste materials from the production process and from the purification equipment. This information is related with the territorial dependence that embraces the knowledge related with the object location, the territory preservation criterion (which evaluates the territory as a reserve, the zone of rest, a settlement, etc.), the data of cadastre of the natural resources used, the data on the soiling background. The temporal attributes (planned and real data) are introduced for every component related with the objects.

The information units, the analysis of which as well as the results of the analysis have the main significance in choosing the decision, are reflected there, e.g., the information on the use of chemical materials or a totality of tasks to ensure the production . One of the questions arising in the design is semantical evaluation of the information sufficient to ground different conclusions. Another question is the selection of the forms of information representation and of the order of conclusions for different groups of specialists.

At the stage of deep knowledge representation we construct a dynamical submodel of the behavior not for the entire enterprise system but only for the chosen information units which are semantically sufficient for the analysis.

Harmful materials, their usage and distribution during the production process are chosen information units the dynamics of which must be analyzed for basic conclusions on the degree of the object contamination. The dynamic submodel is designed by using E-nets at various levels of representation. The E-net of the distribution of harmful materials in the object is shown in pic. 3.1.



Pic. 3.1. The E-net of the distribution of harmful materials in the object.

The semantics of the locations:

$p_1,...,p_n$ -raw materials/stuff from the suppliers;

$b_1,...,b_n$ - raw materials/stuff;

$b_2,...,b_{2+n}$ - raw materials/stuff staying;

$b_3,...,b_{3+n}$, $b_5...b_{5+n}$, $b_6...b_{6+n}$, $b_7...b_{7+n}$ - defective materials;

$b_4,...,b_{4+n}$ - defective materials directly getting into production;

$p_2,...,p_{2+n}$ - harmful materials;

$p_3,...,p_{3+n}$ - defective materials returned to suppliers;

$p_4,...,p_{4+n}$ - reused wastes;

$p_5,...,p_{5+n}$ - finished/semifinished products;

$b_4,...,b_{4+n}$ - raw materials directly getting into production;

$b_7,...,b_{7+n}$ - defective materials directly getting into production;

$b_8,...,b_{8+n}$ - raw materials/stuff staying in the storehouses/open;

$b_9,...,b_{9+n}$ - raw materials/stuff from storehouses getting into production;

$b_{10},...,b_{10+n}$ - processing defective materials getting into production;

$b_{11},...,b_{11+n}$ - finished/semifinished products;

$b_{12},...,b_{12+n}$, $p_6,...p_{6+n}$ - harmful materials in the air;

$b_{13},...,b_{13+n}$, $p_7,...,p_{7+n}$ - harmful materials in the water;

$b_{14},...,b_{14+n}$, $p_8,...,p_{8+n}$ - wastes;

The semantic description of the transitions is the following:

a_1 receiving and registering in the supply department of the object;

a_2 distribution of raw materials;

a_3 distribution of defective materials;

a_4 staying of raw materials in the storehouses/open;

a_5 evaporation/spilling/washing away;

a_6 processing of defective materials;

a_7 the production-technological processes;

a_8 the raw materials usage for products;

a_9 throwing out of harmful materials into the air;

a_{10} throwing out of harmful materials into the water;

a_{11} forming wastes;

Another level of detailing is the decomposition of the transitions a_9,a_{10},a_{11}. The decomposition of transition a_{11} (the processes of distribution of harmful materials into the water) is shown in pic. 3.2 .

The semantics of the locations:

$p_8,...,p_{8+n}$ - waste materials from the primary sewage purification plant;

$p_9,...,p_{9+n}$ - waste materials from the common sewage purification plant;

$p_{10},...p_{10+n}$ - materials getting into open reservoirs, which are not detained in urban sewerage system;

$p_{11},...p_{11+n}$ - materials getting into open reservoirs, if there is no the rain water assembling system;

$p_{12},...p_{12+n}$ - utilized wastes;

$p_{13},...p_{13+n}$ - materials getting into open reservoirs, which are not detained in the sewerage system of the object;

$p_{14},...p_{14+n}$ - materials getting into external reservoirs from the leakage pipes of the object;

$b_{22},...b_{22+n}$ - rain water assembling .

The semantic description of the transitions is the following:

a_{10} getting of the harmful materials with sewage into the sewerage system;

a_{12} the urban sewerage system;

a_{13} washing out by rain water;

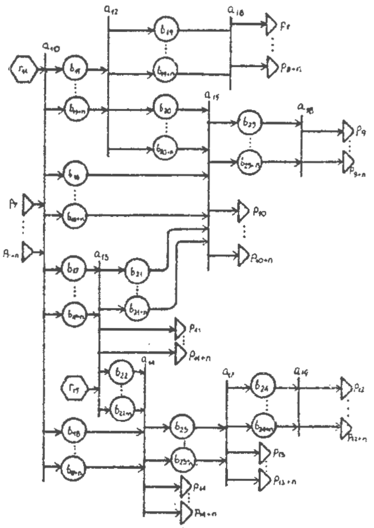
a_{14} the leakage pipes of sewage;

a_{15} a common sewage purification equipment of the urban sewerage system;

a_{16} detaining/settling in the primary sewage purification equipment;

a_{17} a primary sewage purification equipment;

a_{18}, a_{19} utilization of wastes;



Pic. 3.2. The processes of distribution of harmful materials with sewage.

4. Representation of decision making processes using extended E-nets.

The purpose of this section is to show the possibility of applying the E-net formalism in creation and dynamical control of the rules.

The rules will be interpreted there by the set of transitions $A=(a_1,a_2,...,a_n)$ of E-net. The locations $L=(b_1,b_2,...,b_m)$ will correspond to the conditions (facts), so that the condition of applicability of each rule from A consists of simultaneous accomplishment a certain totality $(b_{i1},...,b_{is})$ of conditions. Each condition from the given totality may be a compound vector b_{ik} i.e., may consist of the set of elementary conditions:

$b_{ik} =(b_{ik}(\xi_1),b_{ik}(\xi_2),...,b_{ik}(\xi_n))$.

The rules described by the formalism take the form of production a_i: IF <situation> THEN<action of production> OR<situation>, where the situation is determined by various combinations of accomplishment facts of elementary conditions. The fact of condition $M(b'_{ik}(\vec{\xi}))=1$ means that the token is in the location b'_{ik}. Inference of the state $M(b_{ik})=1$ is the evidence of the statement: $B=M(b_{ik}(\xi_{j1}))\wedge M(b_{ik}(\xi_{j2}))\wedge ... \wedge M(b_{ik}(\xi_{jn}))=1$. The transition having a resolution location r'_i allows to describe the situation in the following way: $M(b'_{i1})\vee ... \vee M(b'_{is})$ or to apply various combinations of conjunctions and disjunctions between $M(b'_{ik})$. The action of production may be determined either by the combination of the facts of condition accomplishment, having some significance for a certain production or the final inference. The net allows to represent various procedures of forming up the rule sequences, that may include consecutive, recurrent, parallel or mixed inferences. Each rule in an inference sequence establishes a new fact. The established collection of facts at a certain moment of inference may be considered as the state of DSS and the productions may be considered as the operators changing this state. The state under consideration may be defined by the vector:

$\vec{M_i} = (M_i (b_j), M_i (b_{j+1}), ..., M_i (b_{j+N}))$ .....(4.1),

where N is the number of positions belonging to a certain fragment of the net. Each of $M_i (b_{j+s})$ may be equal to 1, if the fact is determined at a given time moment t_i (i.e. the token is placed in the position b_{j+s}), or equal to 0, otherwise (i.e. there is no token in the position b_{j+s}).

The whole inference process may be described as the evolution of the dynamic system:

$\vec{M}_{i+1} = a_{ti} \vec{M_i}$ ....(4.2),

where $\vec{M_i}$ is the state before the moment t_i, a_{ti} is the production applied at the moment t_i, $\vec{M}_{i+1}$ is the state after the production application. Assume that the system may remain constant in a certain time interval with regard to the facts being inferred. Thus, it is possible to mark all states $\vec{M}_{i-1} < \vec{M_i}$ which were inferred before the moment t_i. These states may be named as logical consequences of the state $\vec{M_i}$.

The system (4.2) is controlled regarding the time because the production may be chosen from the set A at an appropriate time moment. The terminal or objective set of states will be interpreted by the set of output (terminal or peripheral) locations {p"$_j$} P. From the point of view of dynamic description (4.2), the purpose of inference will be achieved if $M(p"_j)=1$.

The possibility of dividing resolution locations into input and output of the transition allowed to unite the situation of choosing the locations for input as well as for output of the same transition. The procedures of resolution location $\{\psi(r'_i)\}$ for the input of transitions allows to specify the transition firing dependence on the combination of factors of previous transitions accomplishment, the combination of concrete parameters of tokens meaning, as well as the combination of the meanings of external conditions. The procedures of resolution location $\{\psi(r"_i)\}$ for the output of transition allows to specify the combination of a choice of transition completion of tokens transfering into output locations, the combination of choice and/or determination of the dependence of output attributes $\{\xi'\}$ on input attributes and/or the meanings external tokens $\{ p'_i(\xi'_i)\}$ P parameters.

The temporal parameter $t'_p (i) \in T^*$ allows to control the net not only automatically but also according to the planned terms. The temporal parameter $t'_f (i) \in T$ allows to fix the factual moments of transition firing which are directly related with the evaluation of the events described by the given net fragment with respect to time. The abstract conception of specification of temporal relationships allows concretly evaluate of the event described by the given transition regarding other marked time moments. It will allow to formalize the aspects of a decision making mechanism when it is necessary to determine the situations on accomplishment of events (tasks, operations, etc.).

5. Conclusions.

The possibility of the E-nets to represent consecutive, recurrent, parallel processes and to model them in time allows to formalize all possible decisions which are determined by concrete conditions at the real time point . cific Further actions, operations, etc., are specified when a concrete decision is made. By extending the set of macro transitions, introducing different levels of detailing and by using complex procedures of resolution locations it is possible to formalize complex domain behavior processes as well as the representation of these processes in the information system and knowledge base without making the scheme cumbersome. Some temporal parameters introduced in E-net notation allow to control the net not only automatically but also according to the planned terms and to fix the actual moments of transition firing.

The organizational principles of knowledge are supported in the semantic submodel of statical aspects.

6. References

Allen J.E. (1983) Maintaining knowledge about temporal intervals. Communications of the ACM, vol. 267, no 11, 832-843.

Ariav G. (1988). A temporally oriented data model. ACM Transactions on database. ACM, vol. 11, no 4, 499-527.

Brodie M.L. and Silva E. (1982) Active and Passive Component Modelling: ACM/PCM. In: Information Systems Design Methodologies: a Comparative Review, T.W. Olle, H.G. Sol, A.A. Verrijn-Stuart (ed.). Nort-Holland, IFIP. 41-91.

Bussolati U., Ceri S., De Antonellis V. and Zonta B. (1983) Views Conceptual Desig. In: Methodology and Tools for Data Base Design S.Ceri (ed.). IFIP, 25-55.

Casanova M.A., De Castilbo J.M.V. and Furtodo A.L. (1983) Properties of Conceptual and External Database Schemas. In: Formal Description of Programming Concepts-II, D. Bjornen (ed.). Nort-Holland, IFIP,409- 430.

Clifford J. and Warren D.S. (1983) Formal semantics for time in databases. ACM Transactions on database systems, vol. 8, no 2, 214-254.

De S., Pan S. and Whinston A. (1987) Temporal semantics and natural language processing in a decision support system. Information Systems. vol. 12, no 1, 29-47.

Dzemydienė D.J. (1986) On solving the problem of representation of static and dynamic aspects of the information system. Computer Programming. Issue 10. Vilnius 1986, 70-88 (in Russian).

Dzemydienė D.J. (1988). An extension of E-nets for the specification and effective planning and management of the automatic control system . Computer Programming. Vilnius. 1988. Issue 12, pp. 94-104 (in Russian).

Dzemydiene D.J. and Baskas A.S. (1990) The Temporal Knowledge Representation in the Decision Supprt System by Using Extended E-nets. In: Statistical Problems of Control, C. Paulauskas (ed.) Vilnius, issue 88, 66-96 (in Russian).

Gadia S.K., Chuen-Sing Yeung. (1988). A generalized model for a relational database. ACM, vol. 3, no. 6. pp. 251-259.

Gustafsson M.R., Karlsson T., Bubenko J.A. (1982). A declarative approach to conceptual information modelling. In: Information Systems Design Metodologies: A comparative review, T.W. Olle, H.G.Sol, A.A.Verrijn-Stuart (ed.). North-Holland IFIP, 93-136.

Kahn K. and Gorry G.A. (1977). Mechanizing Temporal Knowledge. Artificial Intelligence no 9, 87-108.

Kangassalo H. (1983) Concept D-A Graphical Formalizm for Representig Concept Structures. In: Second Scandinavian research Seminar on Information Modelling and Data Base Management, H. Kangassalo (ed.). Tampere, ser. B, vol. 19, 119-147.

Kangassalo H. (1984). On Embedded Views in Definitional Conceptual Schema. In Third Scandinavian Research Seminar on Information Modelling and Data Base Management. H. Kangassalo (ed.). Tampere. Ser B. vol. 22, 119 - 147.

McDermott D. (1982). A temporal logic for reasoning about processes and plans. Cognitive Science, no 6, 101-155.

Noe J.D. and Nutt G.J. (1973). Macro E-nets for representation of parallel systems. IEEE Transactions on computers, vol. C-22, no 5, 718-727.

Rolland C. (1984) Event Driven Synchronization in Remora. In: Third Scandinavian research Seminar on Information Modelling and Data Base Management, H. Kangassalo (ed.). Tampere, ser. B, vol. 22, 245-275.

Wijers, G.M., A.H.M. ter Hofstede and van Oosterom N.E. (1991) Representation of Information Modelling Knowledge. In: Proceedings of the Second Workshop on The Next Generation of CASE Tools, Veli-Pekka Tahvanainen, K. Lyytinen (ed.). Norway, 159-217.