Temporal Information Management and Decision Support for Predictive Control of Environment Contamination Processes

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Abstract. Temporal knowledge representation aspects are of primary interest in the decision-making context when the problems of dynamic behaviour, process control, monitoring, temporal constraints for data validity, and diagnosis are concerned. Some exceptional features of domain, especially dynamic components, require additional means for knowledge representation, data verification, and assurance of efficient decision-making processes. The integration possibilities of temporal data representation, synchronisation of decision-making and information processing are discussed in this research work. In order to handle temporal uncertainties and manage prediction, it is necessary to design a conceptual model that would enable us to specify requirements to decision support systems of this kind. An approach to temporal information management in enterprise control processes is proposed, by using evaluation nets (the extension of Petri nets). Attention is paid to the representation of decision support processes, in which some future states are important to be prevented and appropriately to act on them. The integration possibilities of real-time process control with retrospective analysis and prognosis components will be described in a decision support system aimed at the environment contamination application domain.

Keywords: decision support system, temporal information, knowledge representation, data validity, evaluation nets.

1 Introduction

The problems addressed in this research are that of developing the method that integrates problem solving and model-based knowledge acquisition and representation describing a dynamically changing environment in an efficiently working decision support system. The technology for building such intelligent systems must provide methods for acquisition, structural representation of many types of knowledge, and assurance of reasoning with respect to time [3].

Application areas where time and change play an important role are process control, resource management, planning, diagnosis, fault detection, etc. Our universe of discourse is concerned with decision-making aimed at the evaluation of the ecological situation of a region. In this environment protection domain it is necessary to deal with dynamic behaviours and temporal constraints on data validity, trends in given time intervals, diagnosis and fault detection of real processes functioning. Some exceptional features of dynamically changing components require additional means for qualitative knowledge representation, data verification, validation and assurance of reasoning with respect to temporal data in order to obtain conclusions about the problem.

Some temporal reasoning aspects have been proposed in knowledge-based systems as expert-system tools and prototype [6], [7], [14]. In some knowledge-based system the data about functioning in past are represented in historical database and the system can obtain the statistical analysis [5]. Co-ordinated functioning of multiple agents has explicitly been expressed in the context of distributed problem solving, based on the extended blackboard methodology [13], [14]. The temporal blackboard approach was developed for real-time process control in [6].

The problems arising in conceptual modelling of static and dynamic aspect representations deal with a difficulty to represent the communication between objects and their interaction with respect to time. Dynamically changing environment, facts, and knowledge impose time constraints. In many conceptual models the behavioural aspects of information systems have been considered (methodologies like ACM/PCM [2], REMORA [17], TEMPORA [18], BIER [19]). Some recent models integrate object-oriented concepts in a conceptual design and reduce the complexity of design tasks by specifying object classes, inheritance links and actions in these classes. Different mathematical schemes are used for creating formal descriptions of dynamic systems, such as: data flow and state transition diagrams, temporal logic techniques, Petri-net classes, abstract communicating methods, etc. However, the problem of expression of behavioural aspects of a dynamic application domain (temporal relationships of process interaction and their determination in time, synchronisation of decision making and information processing, communication between objects, etc.) causes a necessity for additional techniques to specify the requirements of information systems of this type.

A unified framework was developed by using evaluation nets (E-nets) following [16] throughout the analysis of dynamic aspects of application domain [8-9, 12] and relating the use and analysis of information structures with the strategy of decision-making in time. The E-nets allow us to express formally and visually the behavioural aspects of events, processes, and actions in parallel and hierarchical manner without making the schemes cumbersome. In addition, the introduced temporal parameters allow a more precise consideration of behavioural aspects of complex processes.

2 Research peculiarities of a rapidly changing environment

A distinctive feature of rapidly changing systems is the dynamism property related with a state changing in time and space measurements. The environment of this type is usually characterised by the space of states changing, where each state is steady in time for a short period. The complexity of structures of processes, multiple subsystems with their own complex mechanism interacting as internal or external parts, time and space/geographical dependencies, a great volume of data acquired from the processes, and multiple-criteria decision making are essential features for the analysis and representation of such an application domain.

A dynamically changing environment imposes time constraints. Many problems are to be solved simultaneously [15]. The values of the observed parameters may change dynamically, depending on time and the events occurring. Solution of different problems is interfered with one another. For instance, the high concentration of harmful material thrown out into the air is related with the risk factors referring prevention of links that are of biological significance and time-dependent, etc.

Another essential aspect of such an application domain is its spatial dimension. While in many other application domains the problems of study are within a very precise and, usually, narrow frameworks. For instance, the contamination problem of an enterprise (e.g. manufactory, firm, and plant) deals with spatially varying phenomena of unbounded limits.

It is worth mentioning a periodicity property that is displayed in a dynamically changing area. The periodicity components may depend both on the nature seasons of a year, a week cycle, a day or the like. The tasks performed in human activities are also repeated periodically most often. When defining an appropriate time schedule, it is no less important to correctly formulate and represent periodical iterations, repetitions, on the basis of which decisions will be made. Besides, we also face incidental occurrences that may manifest themselves in cyclic processes. However, the analysis of random phenomena, when there is no exact knowledge on such occurrences, is addressed to probabilistic prediction problems.

The complexity of environment research problems consists in the complexity of criteria and differences of attitudes.

3 Temporal information management

Temporal information in the decision support system is bound up with the evolution of process behaviour. Some sub-goals may be determined dynamically during the functioning of the system that adds complexity to scheduling and timing analysis. These features should be considered as requirements to the reasoning method in order to apply them in prevention of some future states.

The main temporal concepts (categories) are distinguished in the decision support system (see Fig. 3.1) following by [1], [7].

T is a time scale and $t_i \in T$ are time moments denoted on this scale. The representation of moments on the time scale depends on the granularity of measurements of time. The hierarchical structure of granularity of time exists between time scales. According to the property of continuity of time, the time interval can be defined by starting and terminating moments (i.e., “begin-time” and “end-time”): $\tau_k = [t_i, t_j]$, where $i<j$ and k is the index of the interval.

The duration of time interval $\Delta\tau_k$ can be defined by numerical expression of difference: $\Delta\tau_k = t_j - t_i$. In the discrete time, perception of the time interval can be defined as a sequence of time moments on the time scale: $\tau_k^d = \{t_i, t_{i+1}, \ldots, t_{i+n}\}$.

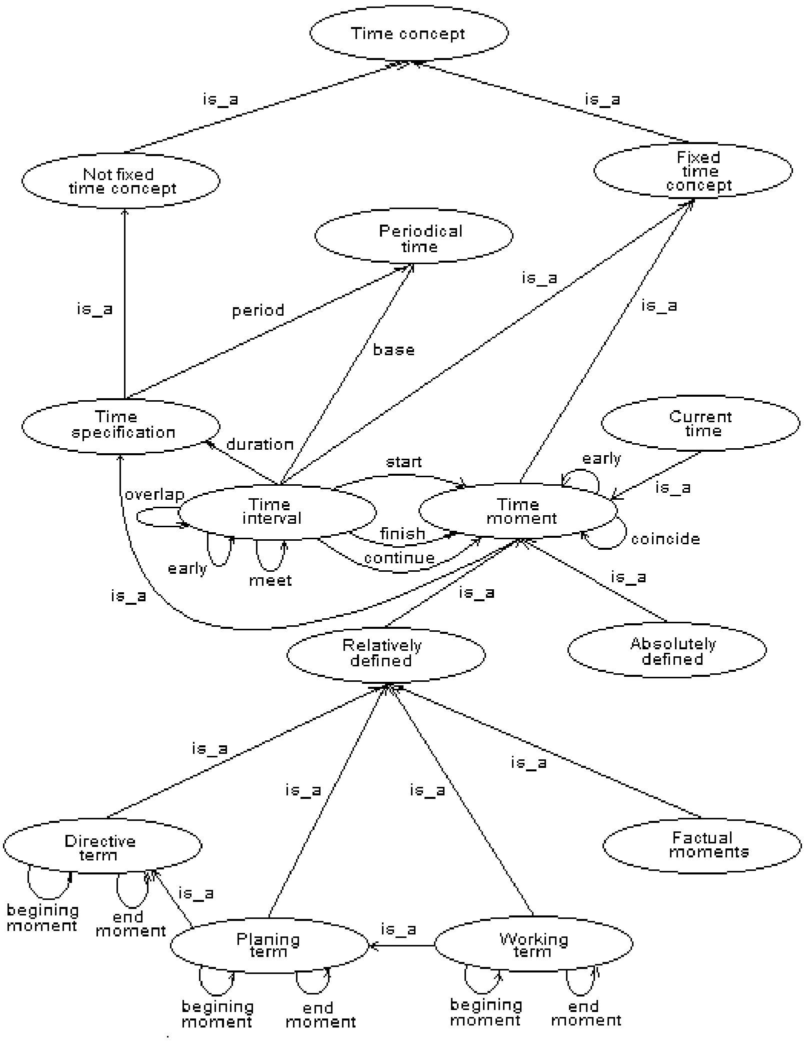

Fig. 3.1. The semantic model of temporal categories distinguished in DSS

A period and a base define the periodical time, where the period can be defined as duration of an interval, and the base may be either a time moment t_i or a time interval τ_k.

The set of temporal relations can be defined between the moment and interval events. A moment event can be represented with "begin-time" equal to "end-time" restriction on the defined time scale *T*.

There exist different temporal concepts in such a decision-making context. Concretely defined and relative time terms are of different significance in constructing plans, imitating and forecasting future processes. The retrospective analysis deals with the assessment of completed events.

The planned terms can be adjusted dependent on the real situation in task executions. For example, if tasks are delayed, adjusted time moments are accepted as the planned ones, but their adjustments must be considered by evaluating the final results of task execution in a DSS.

It is important to have a mechanism that would enable to reason under partial information of event occurrences and their temporal relations. To this end, a set of temporal relations is introduces in DSS according to Allen temporal logic [1] and, in addition revealed some temporal relations between the moment and the interval events as presented in [7].

The examples on the rules of inference of new facts are constructed on the basis of an exactly revealed set of temporal relations and represented in Table 1. The set of evident relations between the moment and interval events is denoted as *R*. The semantics of marking the temporal relations corresponds to Allen's temporal relations [1]. For example, = means equal among interval events, o – overlap, m – meets, > – early, < – later, d – during, df - during finishes, sd - starts during, etc. For the representation of relations among the moment events we introduced points (e.g., e_i **.>.** e_j – the moment event e_i is early to the moment event e_j).

Table 1. Examples of inference rules of temporal relations

No	Inference rule	***Subset of temporal relations applied for the rule***
1	$e_1\ R\ e_2,\ e_1\ R\ e_3 \Rightarrow e_1\ R\ e_3$	$R \in \{.=., .>., .<., =, >, <\}$
2	$e_1 = e_2,\ e_1\ R\ e_3 \Rightarrow e_1\ R\ e_3$	$R \in \{.f, >, <, <o, o>, sd, d, df, <m, m>\}$
3	$e_1 < e_2,\ e_3\ R\ e_2 \Rightarrow e_1 < e_3$	$R \in \{d, sd, df\}$
4	$e_1\ d\ e_2,\ e_2\ R\ e_3 \Rightarrow e_1\ d\ e_3$	$R \in \{d, sd, df\}$
5	$e_1 < e_2,\ e_2\ R\ e_3 \Rightarrow e_1 < e_3$	$R \in \{<o, <m\}$
6	$e_1 > e_2,\ e_2\ R\ e_3 \Rightarrow e_1 > e_3$	$R \in \{o>, m>\}$
7	$e_1 > e_2,\ e_3\ R\ e_2 \Rightarrow e_1 > e_3$	$R \in \{d, sd, df\}$
8	$e_1\ d\ e_2,\ e_3\ R\ e_1 \Rightarrow e_3\ d\ e_2$	$R \in \{d, sd, df\}$
9	$e_1\ sd\ e_2,\ e_2\ df\ e_3 \Rightarrow e_1\ d\ e_3$	
10	$e_1\ R\ e_2,\ e_2 <m\ e_3 \Rightarrow e_1 < e_3$	$R \in \{d, sd, <m\}$
11	$e_1\ df\ e_2,\ e_2 <m\ e_3 \Rightarrow e_1 <m\ e_3$	
12	$e_1\ m>\ e_2,\ e_2\ m>\ e_3 \Rightarrow e_1 >$	

No	Inference rule	*Subset of temporal relations applied for the rule*
	e_3	
13	$e_1 .s\ e_2, e_2 < e_3 \Rightarrow e_1 .< e_3$	
14	$e_1 .s\ e_2, e_2 > e_3 \Rightarrow e_1 .> e_3$	
15	$e_1 .s\ e_2, e_3\ R\ e_2 \Rightarrow e_1 .< e_3$	$R \in \{d, df, m>, >, o>\}$
16	$e_1 .d\ e_2, e_2\ R\ e_3 \Rightarrow e_1 .d\ e_3$	$R \in \{d, sd, df\}$
17	$e_1 .s\ e_2, e_2\ sd\ e_3 \Rightarrow e_1 .s\ e_3$	
18	$e_1 .< e_2, e_3\ R\ e_2 \Rightarrow e_1 .< e_3$	$R \in \{=, d, sd, df, m>, >\}$
19	$e_1 .f\ e_2, e_2 <o\ e_3 \Rightarrow e_1 .d\ e_3$	
20	$e_1 .f\ e_2, e_2 <m\ e_3 \Rightarrow e_1 .s\ e_3$	
21	$e_1 .f\ e_2, e_2\ m>\ e_3 \Rightarrow e_1 .> e_3$	

If the information on metrical data of events is known, we can construct rules and get measures and more precise information about the duration, starting and finishing moments, etc. The examples of rule constructions for inference of metrical temporal relations are represented in Table 2.

Table 2. Examples of the rules of inference of new metrical temporal relations

22	$e_1``(<)^n\ e_2', e_2``(<)^m\ e_3' \Rightarrow \begin{cases} e_1''(<)^{n+j+m}\ e_3', if \Delta(e_2) = j \\ e_1'' < e_3, if \Delta(e_2) is unknown \end{cases}$
23	$e_1'(df)^n\ e_2', e_2'(df)^m\ e_3' \Rightarrow e_1`(df)^{n+m}\ e_2'$
24	$e_1''(sd)^n\ e_2'', e_2'(sd)^m\ e_3'' \Rightarrow e_1`(sd)^{n+m}\ e_3'$
25	$e_1``(<o)^n\ e_2', e_1``(<o)^m\ e_3' \Rightarrow \begin{cases} e_2''(.<.)^{m-n}\ e_3'', if n < m \\ e_2''(.<.)^{n-m}\ e_3'', if n > m \end{cases}$
26	$e_1``(<)^n\ e_2', e_2``(<o)^m\ e_3' \Rightarrow e_1\ (<)^{n+m}\ e_3'$

The measures of duration of time intervals *n, m* and *j* are applied in these rules. We denote the starting time moment of the interval event as e_1' and by $e_1``$ - the ending time moment. We suppose that time moments are fixed with respect to the same time scale *T*.

Determining the appropriate time scale of the problem is of major importance when formulating it in mathematical terms and deciding upon it correctly.

4 Representation techniques of behavioural aspects

The method of integration problem solving and model-based rule learning within an extensive model of different knowledge types, describing a rapidly changing application domain is introduced by using evaluation nets (E-nets – the extension of Petri nets). The structure and behavioural logic of E-nets give new features of conceptual modelling as compared to Petri nets. E-nets have much more complex behaviour logic of transition work, some types of the basic transition structures, and detailed operations with token parameters. An exceptional feature is the fact that the E-net transition can represent a sequence of smaller operations with transition parameters connected with events.

Three levels of knowledge representation are distinguished in the system: the semantic model of specification of static aspects of the target system, the model of behavioural analysis of the target system and the model of multiple objective decision-makings. The level of decision-making deals with the analysis of information obtained from the static sub-model taking into account all possible measurement points revealed in dynamic sub-model of such a system.

The modelled system is regarded as direct mapping of the real enterprise system, and decisions can be based on decisive facts and follow rather deterministic rules. The introductions of E-nets formal means allowed the reducing of the semantic distance between the actual system functioning and reasoning model.

4.1 Formal description of E-nets

Following [18] it is possible to consider the E-net as a relation on (E,M_0,Ξ,Q,Ψ), where E is a connected set of locations over a set of permissible transition schemes, E is denoted by a four-tupple $E=(L,P,R,A)$, where L is a set of locations, P is the set of peripheral locations, R is a set of resolution locations, A is a finite, non-empty set of transition declarations; M_o is an initial marking of a net by tokens; $\Xi=\{\xi j\}$ is a set of token parameters; Q is a set of transition procedures; Ψ is a set of procedures of resolution locations.

The E-net transition is denoted as $a_i =(s_i, t(a_i),q_i)$ in [18], where s_i is transition scheme, $t(a_i)$ is transition time and q_i is a transition procedure. In order to represent the dynamic aspects of complex processes and their control in a changing environment, it is impossible to restrict ourselves to using only one temporal parameter $t(a_i)$ that describes the delaying of the activity, i.e. the duration of transition. The transition description is extended as $a_i=(s_i,t_i^p,\Delta\tau_i,,\Pi t_i,q_i)$, and described in [ ]. Where s_i is a transition schema and i is the index of transition. t_i^p is defined as a planned moment of transition firing, $t_i^p\in T^*$, and $T^*=T\cup\{t_v^*\}$, where T is the time scale and $\{t_v^*\}$ is the set of time moments determined approximately, relatively, etc. $\Delta\tau_i$ is the duration of the transition working time; Πt_i is the periodic transition time; $q_i\in Q$ is a transition procedure, which according to the rules of transition maps $M\times L'\times\Xi'$ into $M\times L''\times\Xi''$ and determines the flow of tokens $m_s\in M$ with parameters $\{\xi'_j\}$ from input locations $\{b'_j\}_i$ to output locations, taking into account the results of procedure

$\psi(r'_i,r''_i)$ at the actual time moment t_i^f, where $\Xi',\Xi'' \subset \Xi$ are the sets of token parameters $\Xi=\{\xi_j\}$.

The common transition schema s_i is presented graphically in Fig. 4.1. It may consist of the subsets of locations $(L'_i,L''_i,\psi(r'_i,r''_i))$, where L'_i is the set of input locations of the transition in which we separate the subset of input peripheral locations P'_i; L''_i is a set of output locations of the transition in which we separate the subset of output peripheral locations P''_i; r'_i is the location of complex input conditions of transition (i.e., input resolution location); r''_i is the resolution location for the transition output; $\psi(r'_i,r''_i)$ is the procedure of resolution locations. A period and a base define a periodical time Πt_i, where the period is defined as duration of an interval, and the base may be either a time moment t_i or a time interval τ_k.

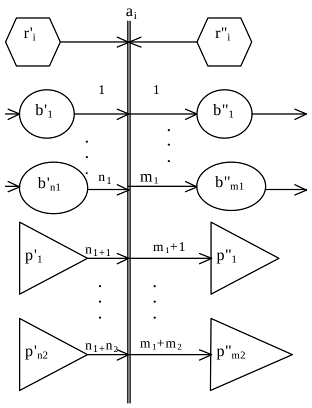

Figure 4. 1. The E-net transition schema

A parameter of token acquires a value according to its identification, when the token is introduced into the location $b_j(\xi_k)$. Such a combination of locations with the tokens in them, the parameters of which obtain concrete values, describes a situation for process execution at a time moment $t_{i.}$:

$$\vec{M}_{t_i} = a_{t_i} \vec{M}_{t_i - 1}$$

where $\vec{M}_{t_i-1}$ is the state before the moment t_i, a_{t_i} is the transition applied at the moment t_i, $\vec{M}_{t_i}$ is the state after the transition application.. Such an understanding of the transition procedure enables us to introduce the time aspects into the procedure of control of processes and to determine operations with token parameters in the time dimension. An exceptional feature is the fact that the E-net transition can represent a sequence of smaller operations with transition parameters connected with the event/process. Operations are described in the transition procedure with these parameters.

The E-nets support a top down design in a graphical representation manner. The hierarchical construction of a dynamic model is simplified by representing macro-transition and macro-location constructions. The input locations L_i' of the transition correspond to the pre-conditions of the activity. The output locations L_i" correspond to post-conditions of the activity. The complex rules of transition firing are specified in the procedures of resolution locations Ψ and express the rules of process determination.

4.2 Modelling and behavioural analysis of the target system

The knowledge representation framework supports organisational principles of information in a static semantic model. The model of behavioural analysis of the target system shows the dynamics of observable processes. One of its characteristics is a need for a lot of data to properly model and verify these problems. A precise structure of information with respect to their time and geographical links must be constructed. An adequate imitation model of the behavioural analysis allows us to predict a further evolution of the target system and to increase the quality of decision-making.

First of all, a dynamic model (DM), based on the extension of E-nets, is constructed for the aim of expression of behavioural aspects of the activities: the interaction and causal execution of events and processes, operations on object classes, life cycles of processes. The hierarchical construction of DM is simplified by the representation of macro-transitions and macro-locations. A dynamic sub-model is designed using E-nets at various levels of representation.

An example of the E-net graphical schema at one level of abstraction of the representation is presented in Fig. 4.2. The structure of processes for distribution of raw materials in an enterprise and formation of harmful materials is represented in such a schema.

A semantic description of positions and transition of this net is as follows: raw materials ($p_1,\ldots,p_{1n}$) are received from suppliers and are registered in the supply departments of the enterprise (a_1).

These raw materials ($b_1,\ldots,b_{1n}$) may be distributed internally (a_2) as follows: one part of the materials ($b_2,\ldots,b_{2n}$) may be left in storehouses, or open in the territory (a_4), another part is rejected as defective ($b_3,\ldots,b_{3n}$), and a third part ($b_4,\ldots,b_{4n}$) may be delivered directly into the production technological processes (a_7).

Defective materials may be distributed (transition a_3) as follows: one part ($b_5,\ldots,b_{5n}$) may be left in storehouses or open in the enterprise territory (a_4), a second part ($b_6,\ldots,b_{6n}$) may be pre-processed (a_6) before entering the production, a third part ($b_7,\ldots,b_{7n}$) may be sent directly to the production technological processes, and a fourth part ($p_3,\ldots,p_{3n}$) may be returned to the suppliers. During the production technological processes (a_7) the materials may be distributed as follows: one part ($b_{11},\ldots,b_{11n}$) is used for ready or half-ready products (a_8), another part ($b_{12},\ldots,b_{12n}$) is emitted into the territorial air (a_9), a third part ($b_{13},\ldots,b_{13n}$) is included in effluent water (a_{10}), and a fourth part ($b_{14},\ldots,b_{14n}$) forms waste materials (a_{11}). In the case they stay in the storehouses or in the open, raw materials may evaporate, be split or washed away with a rain water (a_5).

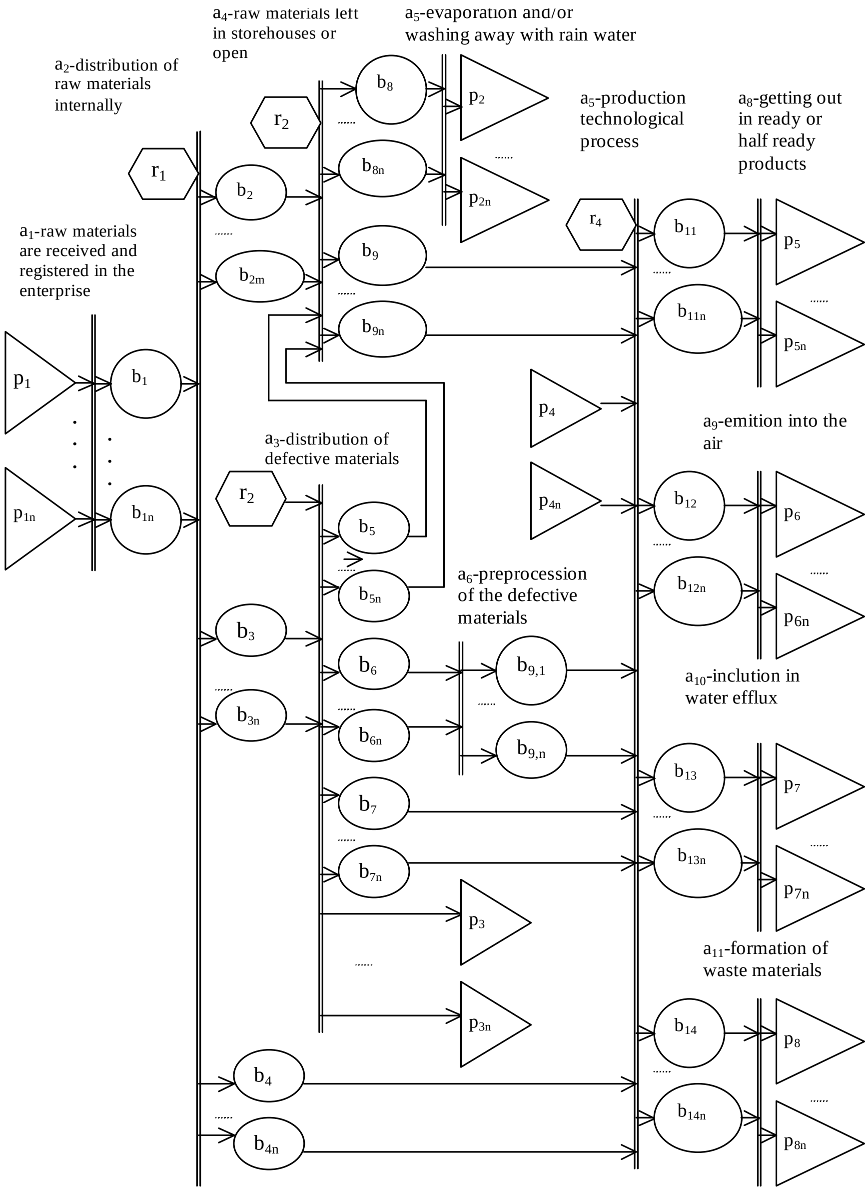

Fig. 4.2. The E-net structure of processes for distribution of materials in enterprise

In order to formalise the functioning of an E-net, we must describe the structure of positions by their parameters and the procedures of transitions with respect of resolution locations and thus to specify the flow of information (or messages) in the target system.

Another level is a decomposition of transitions that are semantically sufficient for a detailed analysis. The design and decomposition of the processes of distribution of harmful materials in the water is presented more in detail in [9, 12]. The representation of decision-making processes for evaluating water pollution is described, too.

A semantic model of the information base is constructed according to the objects revealed in the DM.

The analyst of the environment contamination evaluation system determines the type of problem by using the knowledge about the types of abnormal situations (e.g. alarms, faults, etc.). To make such a diagnosis we must know the topology of the domain for controlling such abnormal situations.

The topology is described by the semantic sub-model of static components and constructed by using three types of abstractions of the chosen entities (aggregation, generalisation, and transformation). This is the scheme of "workspace" of an operating memory that represents content relationships between object types and classes.

The DSS must be able of extracting common and specific knowledge, representing dynamic and static aspects of information environment and using it in real decision situations.

5 Decision support performance

Research of the information and decision processes with important dynamic components is associated with the analysis of real system conditions at the moment of decision-making. A real situation is the result of system development activities (history) and, in order to evaluate the situation in a decision support system, a retrospective analysis of the activities is made. The decisions made have a direct effect on a further development of a system.

In fact decisions bear some risk elements, and, naturally, the goal is posed to decrease the error probability in a decision made by ensuring the information completeness and reliability. First of all, the problem and its structure are identified in the decision-making process and a survey of the necessary data performed. Later on, other possible models for solving the problem are analysed. Specific operation performing variants are correlated with these models. In the next stage, an optimal plan is selected out of a set of possible alternative decisions.

The rules in a given system will be interpreted by the set of transitions $A=\{a_1, a_2,..., a_n\}$ of the E-net. The locations $L=\{b_1, b_2,..., b_m\}$ will correspond to conditions (facts), so that the condition of applicability of each rule consists of simultaneous accomplishment of a certain totality of conditions $\{b_{i1},...,b_{is}\}$. Each condition from the given totality may be a compound vector, i.e., may consist of the set of elementary conditions. The "truth" or "falsities" of various combinations of elementary conditions determine the rule applicability. The transition having a resolution location allows the situation to be described by using various combinations of conjunctions and disjunction among $M(b_{ik})$. The result of a rule may be either the combination of conditions making another rule, or a final inference.

The purpose of the analysis of the rule system is finding the sequence of the rules implying the fact we are interested in. The net allows representation of various procedures forming sequences of rules that may include consecutive, recurrent, parallel or mixed inferences.

Real-time subsystem is embedded in the target system as a concurrent computing system related with the monitoring of data. The monitoring subsystem connected with expert subsystem must detect the faults of process performance. The time for obtaining a solution is often strictly limited. These conditions impose strict deadlines on the obtaining a decision and maintaining the functioning correctness.

The system behaviour defines a set of temporal dependencies. The system works as multiple agent system. The monitoring subsystems are worked as agents in parallel and the important information is writing on the temporal information registration window (TIRW). The TIRW is organised for co-operation of agents at different levels of abstraction.

The topology of harmful materials constructed as static semantic model is used in co-operation work of agents.

The temporal information management requires handling the following kind of information described in [6] as follows:

- past values will usually be “exactly known” on the used time scale and stored with time parameters (the temporal relations among them can be deduced using e.g. dates and time);
- current values are established at the current time moment and can be assumed as “partially known” and “dependent”.
- future values are used to represent expected or predicted values (their management presents more difficulty due to the lack of knowledge about the exact instant at which they will be produced).

The example of TIRW for controlling of some important parameters of sewage characteristic is shown in Fig. 5.1.

The information is affected by level of uncertainty. If the uncertainty is associated with the value itself, we deal with information with confidence measure, for instance, the concentration of copper (Cu) will be 0,04 mg/l with the confidence of 90% in time t_{k5}. If the uncertainty is associated with temporal occurrence of the values, we deal with another kind of information, for instance: in the next 60 min the concentration of Cu will be 0,04 mg/l. The temporal occurrences of values are important in constructing of rules of the knowledge base.

The conditions of complex process control cause the necessity to work with the evolution of process functioning variables. Besides, it is necessary to work with future values, in order to secure prognosis and managing predictions of undesirable functioning. The process control subsystem must detect such facts: what the maximum value of parameter was in concrete time interval; the number of times a value exceeded a predefined reference value (i.e., the limitations of concentrations of harmful materials in the sewerage water), as well as the temporal delay between the maximum of a variable, and the maximum effect on another variable.

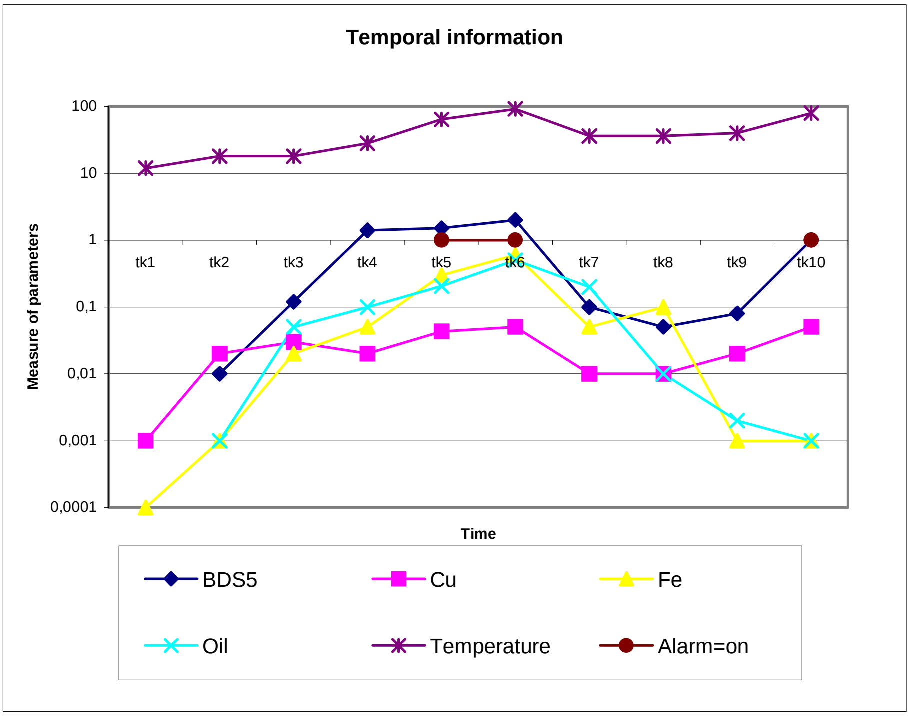

Fig. 5.1. The example of temporal information registration window

The accessible degree of values affects another parameters, which are time dependent. When the causal facts occur (e.g., the temperature of sewage exceeds the limits and/or the concentration of harmful materials reach the greatest permissible limitations), the dependent fact gets a status (e.g., Alarm=on). Such fact entered in TIRW activates another agent which function is to influence the technological process. If such situation does not occur, then the dependent fact will not occur.

In order to identify necessary data, management and control structures, and information processing abilities, one has to imitate a cognitive task in the decision support system.

The courses of decision management and the basic sequences of functional reasoning are joined with information processes as a result of which the evaluation states are obtained. By a decision we mean reasoning (evaluation, determination, resolution, etc.) that has to follow certain actions. An ordinary determination - from certain assumptions to certain generalised conclusions may serve as a preliminary preparation of these actions.

A preliminary preparation of actions, however, is "stimulated" not only by preliminary assumptions and hypotheses but also is stimulated by the aims and goals of decision-makers. Automatic generation of alternative solutions implies the use of semi-automatic methods for comparing these solutions. The complexity of the decision making task consists in finding the best decision under multiple criteria. As the number of alternative increases, multi-criteria evaluation involves a mechanism for rejecting a number of those alternatives.

Analysing the possible choice mechanisms (under lack of information about the importance of criteria, or assuming the criteria are equivalent), the acceptable decision variant seems to be not so easily chosen. It is expedient to make a choice according to a weighed criterion. Then the basis for choosing the decision variant is qualitative information on the relative importance of each separate criterion.

The essential part of a decision support system is the model of a decision process. Referring to the decision support performance analysis in is important to represent the relationships between the individual steps in decision-making and the control network ensuring proper application of the information environment and the knowledge base. A description of this meta-model must include the model of goals, plans and must represent the practice and strategy of reasoning of specialist-experts in making the decision. At the stage of analysis and evaluation of the enterprise performance, the use of this meta-model could allow:

- to recognise what changes in the environment may induce changes in decision goals;
- to decide is the situation relevant for the ready application of existing rules or not;
- to specify the process of identification of possible courses of actions and alternatives and to control the choice of concrete variant of these actions by evaluating attractiveness of the consequences of each action.

The multiple objective decision making level deals with the analysis of information obtained from the static sub-model taking into account all possible measurement points revealed in dynamic sub-model of such a system. The task structure relationship with information elements, the course of decision-making processes and presentation of alternative variants of decisions are represented in this sub-model. The modelled system is regarded as direct mapping of the real enterprise system, and decisions can be based on decisive facts and followed rather deterministic rules.

Conclusions

The consideration of real time process control is organised by the integration of retrospective analysis and prognosis components. The level of representation of dynamical aspects shows the dynamics of observable processes. The monitoring subsystems are worked as agents in parallel and the temporal information window organises the communication.

The multiple objective decision making level deals with the analysis of information obtained from the static sub-model taking into account all possible measurement points revealed in temporal window of dynamically changed information.

The modelled system is regarded as direct mapping of the real enterprise system, and decisions can be based on decisive facts and follow rather deterministic rules. Further actions, operations, etc. are determined through the mechanism of co-operation of agents, which are working by using the temporal information registration window.

The method of applying E-net formalism to represent decision-making process is introduced. The use of E-nets to represent consecutive, recurrent, parallel processes and to model them in time allows formalisation of all possible decision, which may be determined by concrete conditions at real time point. Extending the set of macro transitions, introducing different levels of detailing, and using resolution location procedures, it is possible to formalise the behaviour of complex processes as well as the knowledge without making the scheme cumbersome.

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