Creation of ontology for planning and scheduling

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Abstract: *The paper deals with a problem of interchange knowledge among various computer systems (created by different programmers, in different times, in different languages, etc.) A solution offers an ontology creation. Ontology can be viewed as a conceptualization of general knowledge into general readable and understandable format. The paper proposes a frame for creation ontology for manufacturing systems, especially for scheduling and supply chain management (SCM).*

Keywords: *ontology, scheduling, KIF,*

1 Introduction

Ontology usually consists of a set of classes (or concepts), definitions, property definitions and axioms about them. The classes, properties and axioms are related to each other and together form a model of some systems or in general of the world. We suppose that a change constitutes a new version of the due ontology.
Ontological Engineering is a very young area in Artificial Intelligence. There exist some metrological proposals for building ontology.
Developing ontology contains the following steps:
Specification - which may be the determination of classes (Section3.1, 3.2)
Conceptualization - which is the modeling at the knowledge level using for example tables and graphs. The proposed tables and graphs allow modeling, concepts, attributes, first order logic formulas etc. and they are thought to be manipulated by experts in domain to be modeled. The methodology does not propose how to add a new type of table, how to add a new field to a type of table, how to delete one of the types of the proposed graphs, or how to elaborate a completely new modeling way with completely new graphs and tables. Therefore in several groups in different location (or different situation) have to build an ontology collaboratively, There are

problems to agree and change the characteristics of the tables and graphs to be used. (Section 4)
Formalization - using for example a formal language or some frames. (Section 5)
Implementation - using for example a special language of ontology. (Section 6 – Conclusion)
It is needed to notice that the potential of ontology is evident, but the fundamental notions remain largely intuitive. Notably there is neither precise characterization of the notion of ontology, nor what is for two ontologies to be integrated.

2 Proposed solution

One of the possible solution may be established in two phases using the, so-called, meta way.
First phase consists of:

- meta specification
- meta conceptualization
- meta formalization
- meta implementation.

Second phase consists of:

- specification, conceptualization using the meta model (meta tables, meta graphs) obtained in the first phase
- formalization and implementation of the ontology.

For the facilitation and implementation of the building of meta models in our case a reference meta model may be proposed. Further we suppose that it is possible to modify the reference meta model according to modeling requirements of each ontology. Such meta model is expressed by means of meta tables and meta graphs, and it is also formally expressed. Then the reference meta model allows building ontologies with:

- concepts
- class and instance attributes
- facet of such attributes
- relations
- first order logic formulas or other logical formulations
- instances.

These components appear in the reference meta model because each one of them have been in some ontologies developed during the experimentation.

3 Approaches of ontological methodology to planning and scheduling in production systems and supply chains

Because recently in the family of production systems and supply chains the research is focused to their development, it could be very interesting to deal with the possible application of the ontological methodology to improve their performance.

3.1 Characteristics of the production systems

Production systems (PS) belong to large systems which are defined as backward systems, where primary inputs are production requirements, production concepts, systems parameters, etc., and primary outputs are final products and quality of the products. From this point of view, generally their performance can be divided into five parts:
planning, scheduling, simulation, control and execution.
Planning process represents the periodical activity and aims to obtain the best scheduling of material flow. Planning in manufacturing can be just difficult. In planning, one must deal with detailed data, summary data, internal - external data, subjective information, and sometimes with no information at all.
The scheduling in PS may be defined as the process of allocation of limited resources to production tasks on the basis of such information as for example: machine characteristics, production requirements, time of performance, production constraints and economical factors.
The control system determines by the control technologies the sequences of control action for the resources used in the actual manufacturing process.
The role of execution is to follow the performance of the system and to give backward information for the control system, which on the base of this information creates the new available sequences of control action.
The phases: planning, scheduling, control and execution may be more concurrent and it is needed to consider with the cycle time for each of phases and also for the whole cycle.
The common approach to the solution of described problems was based on a rigid, sequential, one way set of deliverables leading eventually to a finished system. Usually by the time the system was finished, the requirement had changed.
Newer systems development methodologies are based on rapid, concurrent prototyping with frequent feedback to validate the requirements. Realization of such approach requires parallel coordination, rapid obtaining and treating the information and also rapid communication. Then we can obtain also the actual state and the production dynamics.

A production network is a basis for a representation of a flexible production line. A flexible manufacturing system (FMS) can be obtained by connecting of numerous flexible PLs.
For a description of a process in a production network a required technological task TT_j ; $j = 1, 2,..., m$ assigned to a production device V_i (for example NC machine); $i = 1,2,...,n$; a server R_i (robots), and a transport device Tp_l $l = 1,2,...,k$, which make up the PL, is considered. The PL may be characterized by capacity, reliability and economical parameters of utilized devices. In actual processes, however, it is necessary to consider the perturbation, as, for example, the change of system parameters, the device down, the change of production plan, etc.. For the compensation of the perturbations the relation among system parameters and perturbations must be known. On the basis of this knowledge, the influences of the perturbations at the system parameters, development of the reliability of devices and the control actions could be determined. A technological task is a function of number of workpieces *Wp,* cost of production *K*, quality of production *Qb,* and number of final products *Fp* :

$$TT_j = f\,(Wp,K,Qb,Fp\,) \qquad (1)$$

The PL may be characterized by the capacity *C*, reliability *RL* and economical parameters *KD* of production devices, servers transport devices, which can be expressed by the relation:

$$PL\,(Vi,\, R_i,\, Tp_i) = F\,(CiV,\, C_{iR},\, C_{iTp},\, RL_{iV},\, RL_{iR},\, RL_{iTp},\, KD_{iV},\, KD_{iR},\, KD_{iTp}) \qquad (2)$$

3.2 Characteristics of supply chain management

A supply chain is considered as a loop from customers' demand to customer's satisfaction by final product or service. It is made through a chain of producers, suppliers, distributors, and transporters. A supply chain is a complex and dynamic system, which has a character of hybrid-distributed system. In MAS language, a supply chain can be modeled as a system of intelligent agents, which agree to cooperate to reach the final goal. A new, modern, and cost-effective implementation of supply chain management (SCM) is enabled by rapidly developing information and communication technologies.
SCM is a process of creating and configuring a supply chain, identifying measuring metrics in the chain, determining weak points in the chain and work to achieve the best results to meet customer demands.
Supply chain management where the plan – is a strategic portion of management and the aim is to develop strategies for managing all resources (raw, materials, services) and balance cumulative demands and supplies includes five following steps:

Develop a set of metrics to monitor the efficiency of SC
Source - the aim is to choose a set of suppliers for producing goods and services. The part of this step is pricing, delivery, and payment process. Goods and services are received and transferred to manufacturing facilities
Make - goods and materials are transformed to final products. It is a manufacturing portion of SC. All activities necessary for manufacturing are done through this step: scheduling, testing, packaging, prepare for delivery.
Deliver - coordination orders from customers, developing a network of warehouses, distribution and transportation of products to customer, invoicing system to receive payments from customers. It is par also known as "logistics".
Return - deals with a problematic, defective products, how they are returned to producer.
Each basic SC is a chain of Source, Make and Deliver process. A SCM is different for various systems, depending on specific requirements, which must be analysed in a process of establishing a SC. The two basic classes of producing systems are well known. They are "produce-to-stock" and "produce-to-order". Dairy and bakery are very specific among other industries. Products must be delivered fresh and produce to stock is not allowed from the point of effectiveness. A very close co-operation of all parts in a SC is strongly required. Specific order policies are proposed to avoid over-production. Conversely producers are anxious to satisfy customers' demands in order not to loose any of customers. A market driven model of production management is proposed to manage such a system of SC. The basic scheme of SC is shown in Figure 1. Production gets customers' demands and purchases material from suppliers on the basis of this demands. Products are delivered to distributors where they are for sale for customers.

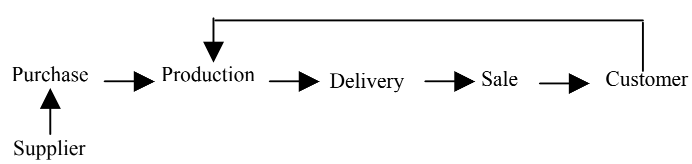

Figure 1 A basic scheme of SCM

3.3 Negotiation as a tool for managing a supply chain

A system of three components; supplier, producer, and distributor, is considered. There are three agents that represent three parts of the system. Agents agree to cooperate in order to achieve the common goal. The criterion to accept compromising solution is the maximum pay-off for the system as a whole. It is not required to achieve partial goal with the maximum pay-off. All agents are autonomous and intelligent. Their decision-making is based on the Markov decision process.

Each agent has its own priority rule, how to evaluate cooperating process. Negotiation process ensures the best solution for the system as a whole.

3.3.1 Negotiation algorithm and rules

Each agent randomly chooses a plan according to its alternatives. Alternatives for all agents are evaluated, that is a reward for each agent is calculated. A global criterion functions, for proposed agents' plans, are evaluated.
According a global criterion function an alternative for all agents is chosen and a profit for all agents accepting this chosen alternative is calculated.
Negotiation process starts: If the chosen plan does not satisfy (in many cases) all agents requirements, agents propose another plans to evaluate and negotiate. Then step 1 is repeated.

Let k is an agent from [1,n]. A reward function of agent k is $a_k(x)$. Each agent is associated with a weight w_k.

If $\sum_{k=1}^{n} w_k = 1$, then a combined reward from all agents can be expressed as

$$a(x) = \sum_{k=1}^{n} w_k a_k(x) \tag{3}$$

Each agent is associated with a set of possible alternatives. Let α_{ik} is an alternative i associated with an agent k.
Rewards of an agent are defined as a difference between positive and negative rewards. A positive reward is a function of profit and gain of an agent, and a negative reward is a function of costs, e.g. production costs, distribution costs, spending and lost.
A reward function for an agent depends also on an alternative plan for this agent.
Let

$$a_k(x) \mid \alpha_i = a_k(x)\alpha_{ik} \tag{4}$$

is a value of rewards for agent k using an alternative α_{ik}.
To evaluate alternatives an average value of a_k is computed.

$$avga_k(x) = \frac{\sum_i a_k(x) \mid \alpha_{ik}}{I_k} \tag{5}$$

where I_k is a number of alternatives associated with an agent k.

Then a difference between avg a_k and a value of $a_k(x)|\alpha_{ik}$ is calculated for all alternatives.
The weight of 1 is given to an alternative plan, where the $a_k(x)|\alpha_{ik}$ is the maximum.
Other alternatives are inhibited. They are given weights of 0 (zero).
For negotiation process it is necessary to establish weights that are corresponding to rewards, but in such a way that no alternative is given a weight of 0 (zero). In that case the negotiation process cannot be executed.
A relative weight of an individual agent alternative can be interpreted as a probability unit with which the alternative is chosen.
Let define a weight as follows:

$$w_k \mid \alpha_{ik} = \frac{a_k(x) \mid \alpha_{ik}}{\sum_i a_k(x) \mid \alpha_{ik}} \qquad (6)$$

It is clear that

$\sum_{k=1}^{n} w_k = 1$ for all agents *k*.

After weights are assigned to alternatives a negotiation process starts.
Each agent prefers an alternative with the highest weight. A global criterion for choosing an alternative is a global reward for the whole system, which is a function of rewards of all agents. A value of criteria function is calculated and if it is higher then an average value of criteria function for the whole system, negotiation process stops. If it is less, agents are sequentially called to make another offer, that means, to admit an alternative with a worse results for its, but maybe the whole system results would be better.
Negotiation runs in loops. For the beginning the first agent is called to compromise and all other agents keep their highest bids, then the second one, etc. Such a way of negotiation doesn't require backing up all values to find a sub optimal solution.

3.3.2 Reinforcement learning in a process of negotiation

The system is trained with randomly generated examples, using different parameters and applying each particular priority rule.
Reinforcement learning (RL) is learning from interactions in uncertain environment. Usually the goal is not known. The learner has to pick an action and try it and then to choose, which of action yields the best rewards. The four basic sub elements of RL are:

- A policy – which is a function that associates a state to an action. It can be also a lookup table.
- A reward function – as it was defined in section 1, eq. 3 and 4.

- A value function – opposite to a reward function that answers a question what is good now, a value function yields results in long run term. It is a prediction.
- An environmental model – it is not required.

A general RL algorithm:

- At each time t following steps are performed
- For all actions a a reward is evaluated
- For each state s a value function is computed
- The final output at time t is $Q(t) = \sum q(t)$
- A new state is establish
- Go to step 1 at time $t+1$

A backup operator takes into account only action with the best reward. The states with many good actions are neglected, that is one of disadvantages of the algorithm.
For more detailed description see [6].

4 An ontology approach to the solution of the PS and SCM planning and scheduling

For the creation of PS and SCM ontology it is needed to consider with the answers to the following questions:
What tables and graphs will be used for conceptualisation of ontology
What recommended order is needed to fill in the tables and to build graphs.
It could be specified that the tables used during the conceptualisation of the ontology is the concept dictionary. The possible fields of such tables would be: concept names, instances, instance attributes, etc., as it is introduces in Section 1.
From this point of view, the definition of notions of compatibility in terms of ontological content is required.
On the basis of assumption, applying of the tables and graphs, which characterise the required performance of PS and SCM, is possible, as a reference meta model (RMM) for the building of their ontology.
Supposing a possibility of modification of RMM according to the modelling needs, tables Table 1, Table 2, and Table 3 may be taken as a meta tables in the first phase of the SCM ontology determination. The second phase may be denoted as the ontology development if a new table and a new meta model is obtained. This is a case of changes in customer's demands.
Representing the SCM ontology by meta tables, meta graphs and meta reference model for the meta conceptualisation and meta formalization, the multi agent system (MAS) technique may be used. The negotiation rule of MAS may be applied, for

example, in the dialogs during the SCM performance. The possible solution of so formulated problem is shown in Figure 2.

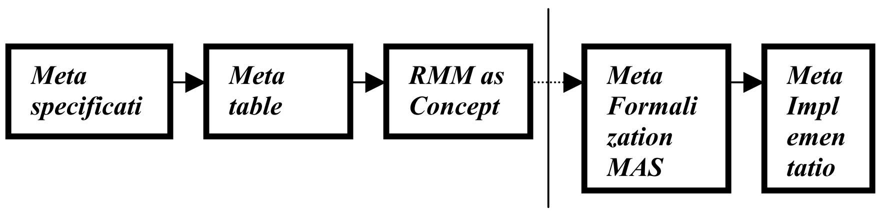

Figure 2: Solution sequences

We suppose that if the tables and graphs change a new RMM is created.

5 Formalization - An informal frame for creating of basic definitions for scheduling and planning

In order to ensure interchange of data among various computer systems, an effort to standardize and normalize data formats is made. One of languages dealing with this problem is KIF (Knowledge Interchange Format). KIF enables conceptualization of the scheduling problems in terms of objects and relations among these objects. In KIF, relationships among objects take the form of relations. A specific kind of relation is a function. A function is defined as a set of objects, one for each combination of possible arguments. Arguments are initial elements and the final element is a value of the function. KIF also enables to treat each expression as an object and that way to formalize knowledge about knowledge – meta knowledge. A complex expression is conceptualized as a list of its immediate sub expressions. Each of sub expressions may be either elementary or complex expression.

Scheduling ontology defines basic classes as follows:

1. Basic elements of scheduling and their relationship
   a. resources
   b. activities
   c. constraints
2. Basic demand components and constraints
   a. hard constraints
   b. soft, temporal constraints
   c. time and resources' constraints
3. Transportation domain specification
   a. transportation resources

b. transportation constraints
c. transportation activities

4. Ontology of instances

Each class has a subclasses and relations among them defined.
The system requires a data model for scheduling.
Data may be organized as in the Table 1. Resources are defined through their operating times. Operating times depend on which task and which operation is processed. In Table 1, P_{ij} means processing time for the *j* task in production line *i* and O_k means the *k* operation within the *i* production line (PL).

OPERATING TIMES	**Operation**	**Pij**	**Operation**	**Pij**	**Operation**	**Pij**	**Operation**	**Pij**
Transport								
	J1/O1/AGV	6	J2/O1/AGV	6	J3/O1/AGV	5	J4/O1/AGV	2
	J1/O11/AGV	8	J2/O11/AGV	6	J3/O11/AGV	7	J4/O11/AGV	4
Manipulation								
	J1/O2/MR1	3	J2/O2/MR1	2	J3/O2/MR1	2	J4/O2/MR1	3
	J1/O2/MR2	2	J2/O2/MR2	3	J3/O2/MR2	3	J4/O2/MR2	3
	J1/O4/MR1	2	J2/O4/MR1	2	J3/O4/MR1	2	J4/O4/MR1	2
	J1/O4/MR2	2	J2/O4/MR2	3	J3/O4/MR2	2	J4/O4/MR2	3
	J1/O6/MR1	2	J2/O6/MR1	2	J3/O6/MR1	3	J4/O6/MR1	2
	J1/O6/MR2	3	J2/O6/MR2	3	J3/O6/MR2	3	J4/O6/MR2	2
	J1/O8/MR1	4	J2/O8/MR1	3	J3/O8/MR1	2	J4/O8/MR1	2
	J1/O8/MR2	3	J2/O8/MR2	3	J3/O8/MR2	2	J4/O8/MR2	3
	J1/O10/MR1	4					J4/O10/MR1	2
	J1/O10/MR2	3					J4/O10/MR2	2
Machining								
	J1/O3/NC1	5	J2/O3/NC1	4	J3/O3/NC1	6	J4/O3/NC1	-
	J1/O3/NC2	-	J2/O3/NC2	4	J3/O3/NC2	-	J4/O3/NC2	6
	J1/O5/NC1	-					J4/O5/NC1	6
	J1/O5/NC2	5					J4/O5/NC2	-
Turning								
	J1/O9/M1	6	J2/O7/M1	4	J3/O5/M1	4	J4/O7/M1	6
	J1/O9/M2	5	J2/O7/M2	5	J3/O5/M2	5	J4/O7/M2	8

Table 1: Data model for JSS (Job-shop scheduling)

Formal languages for creating ontology have been developing. There exist various formal languages to support creating of ontology in various areas. The ontology for supply chain monitoring may be modeled using Ontology Interference Layer (OIL). An example of creating a formal ontology for a class Order in supply chain management in DAML OIL language is depicted in Figure 3 [8].

Class-def Order
Documentation "A legally binding contract concerning a transaction between a seller and a customer. The contract is fulfilled when the customer has received the product and the seller has received the payment"
Slot-constraint actualDeliveryDate has-value CalendarDate
Slot-constraint plannedDeliveryDate has-value CalendarDate
Slot-constraint dateOfOrderReceipt has-value CalendarDate
Slot-constraint dateOfIssue has-value CalendarDate
Slot-constraint amountOfProducts has-value Integer
Slot-constraint consistOf has-value productName
//SUB: OrderIncoming
//SUB: OrderOutgoing
//SUB: DeliveryOrderIncoming
//SUB: DeliveryOrderOutgoing
//SUB: OriginalOrder

Figure 3: Definition of the concept Order for SCM in OIL-syntax

	α_1	α_2	α_3
g_1	100	120	140
c_1	50	80	120
g_2	120	120	120
c_2	80	90	100
g_3	120	160	210
c_3	60	60	60

Table 2: Gains and costs for three agents and three alternatives

	α_1	α_2	α_3
1	0,45	0,36	0,19
2	0,44	0,33	0,23
3	0,19	0,32	0,49

Table 3Weights for 3 agents and 3 alternatives

6 Conclusion

Many organizations are involved in developing ontologies for different areas (biology, medicine, information technology, public transportation, telecommunications, etc.). The effort is spent on standardizing and formalizing languages to ensure the common readability and understability among humans, computers, and machines. The FIPA standards became the basis for communication in agent technologies. Creation of ontologies represents an open environment for many researchers and developers. The paper is intended to present a general problems and methods of creation ontologies rather than present a special ontology (e.g. scheduling ontology, SCM ontology, etc.). Methodology of creating ontologies is very important in order to develop recently existing ontologies and establish new ontologies into more specific and generic systems, which will be used widely in the defined area. The basic steps in creation of ontologies (specification, conceptualization, formalization, and implementation) were defined. The concept presented here may be used for all classes of scheduling problems, either in JSS, or SCM, or any other scheduling tasks. Generally scheduling ontology may be based on constraints specification (e.g. OZONE ontology) or on task specification (e.g. MULTIS). As far not many ontologies has been applied in real life. There exist a couple of projects dealing with creating onlologies. For instance a project CIPHER deals with a resource allocation problem. The goal of the schedule is to allocate available person to various work packages in order to ensure the complex task will be finished in time.

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