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An Approach to Building Factory Scheduling Expert System By Using Model-Based AI tool

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In this paper, we propose a method to manage production system easily for operators when either equipments or products are changed. And we explain the scheduling AI tool which realizes the proposal method. The tool's knowledge expression consists of models, rules, mathematical expression and fuzzy logic. The model expresses the relations between products and manufacture, and properties of products. The models are separated into three type, equipment model, operation model, and product model. These models are classified by applicable fields as the assembly process or continuous plant process. The model expression of each type is based on object oriented paradigm. We report systems utilizing our approach.

1. Introduction.

When AI(Artificial Intelligence) technology is used, usually, it is difficult that plant operators change programs to manufacture control system in daily work. It is necessary for expanding automation area of manufacture to construct intelligent manufacture system. Further, communications method between men and machines should improve to be easier. We have been researching effective methods to communication between men and machines in the manufacture site. This paper describes an approach to be construct modelling for operator's understandable. In this paper, the considered scope is scheduling work of equipment operation every day.

We propose technique, expression by which relation between equipments and products and by which relations between equipments and operation. And, We introduce the tool based on the technique, AIMAX-P. The application case is reported.

2. Model Expression.

Our proposed model expression of manufacture system is to describe mutual relations between element and element individual of composition of the manufacture system. Model of the manufacture system can be classified from functions as follows.

(1) Equipment model

(2) Product model

(3) Operation model

The equipment model and the product model are not always changed. The operation model is data which changes every day. Next, the detail of each model is explained.

2.1. Equipment model.

Equipment model consists of knowledge concerning the layout of equipments and knowledge which equipment has the peculiarity. There are the following as elements which composes the equipment model.

① Machine
② Buffer
③ Transportation machinery
④ Passage
⑤ Carrying tool
⑥ Palette
⑦ Treatment device
⑧ Worker
⑨ Parts

The machine, the buffer, the passage, and the transportation machinery are fixed and are not transportable. The layout among equipments is reperesented by defining both former equipments and after equipments. Rules represent how to use equipments. When the transportation between equipment becomes a problem, the transportation machinery and the passage will be used. The work from starting point to terminal in the passage is specified. As a result, the content of transportation is expressed. The destination will be specified by the rule as well as the machine

when there is a divergence. The carrying tool, the palette, the treatment device, the worker, and parts move between equipment. It is possible to distinguish by giving the attribute individually.

2.2 Product model.

Product model expresses knowledge concerning method of manufacturing. In the product model, there are information to which the product is peculiar and information related between products. When manufactured product data can be regarded as well as the manufacturing time and the using machine, etc. , is defined by the part information of the equipment data. When it is not possible to regard as well as that, the following item is necessary in each individual product.

① Manufacturing process
② Using parts and the numbers
③ Using machine
④ Using machine selection rule
⑤ Manufacturing time
⑥ transportation method with post-processing or pre-processing

2.3. Operation model.

Operation model represents operation conditions of manufacture plan and the equipment changed every day. There is as a manufacture plan problem for instance in the following cases.

① To decide operation order of equipments when dispatching order is determined.
② To decide dispatching order.

At first case, The following data of each product model will be given as information of manufacture plan.

- Starting time to be dispatched on and dispatching on interval.
- The dispatching on place In addition, the dispatching on number and the input are given to the operation time of the worker and the machine as an operation condition of that time.

Concretely, it is the following information.

- Work time on holiday and weekday.
- Daily operation schedule.
- Nonstandard operation schedules such as regular check and breakdowns.

3. Tool for scheduling plan expert system.

We made tool which mounts models described in Chapter 2. This tool is called AIMAX-P. AIMAX-P is abbreviation of fortran based AI tool of manufacturing computer system for planning. This tool is based on the access function which operates model expression and AI technique. The purpose of this tool is support for the manufacture automatic planning work. The expression of each model adopts object oriented paradigm.

When model is expressed with the object, it is necessary to make the control mechanism at each model in general. In this tool, the mechanism, which controls relations of data between models, is supported. Therefore, the access method between models can be standardized. The model expression and the access method of AIMAX-P will be described in the next section.

3.1. Knowledge expression

The knowledge expression of AIMAX-P consists of model, variable, mathematical expression, rule, and inference control knowledge as shown in Figure 1. And this tool also can express fuzzy rule.

The model expresses the above-mentioned manufacture model. The model means "class" the same as object oriented paradigm. "Instance" is called as model-data in our tool. This merit is to be adding each properties to model a priori when the model is defined. planner should defines the model first. And he should define model-data second. Model-data is instance adding to identifier which model-maker can operate. Relations among model-data represent real plant structure. Both models and model-data can be defined in tables.

AIMAX-P has two types about variables for the input and output. The variable stores temporary information to describe the mathematical expression. Or, it is possible to handle constant data. The variable name can be defined in tables.

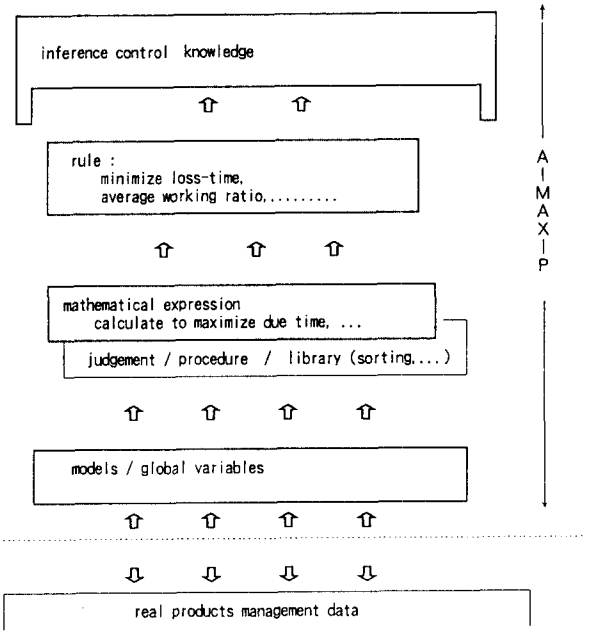

Figure 1. AIMAX-P Knowledge expression

In the rule description, ordinarily, it is difficult to understand what judgements and procedures means only by reading the rule. AIMAX-P has mathematical expression. The mathematical expression is defined in IF-part of the rule and THEN-part by naming. Planner represents the model in this expression. The grammatical description conforms to the FORTRAN expression. AIMAX-P has functions to operate models and to calculate resources as Table 1. So that, planner program less than former. he can operate to defined model data by the name. And so, planner can also program for "do loop statement" by using model data identifier.

The rule has both IF-part and THEN-part. The inference control mechanism can add priority to rules. It is inference control knowledge to define this mechanism. The solving method library in Table 1 can apply functions to the scheduling problems which use in mathematical expression.

3.2. Inference mechanism.

When a planner makes a schedule, his approach is almost as follows from our experiences.

STEP 1. The planner checks plant status and amount of planned products. And he selects allocation method.

STEP 2. The planner allocates jobs one by one among resources which are usable under some conditions.

STEP3. The allocated states will return to the previous state by one if do not allocate jobs.

STEP4. The planner will allocate jobs another method if cannot allocate.

This approach is represented by AI techniques, called backtrack.

AIMAX-P inference engine has backtrack mechanizm as shown in Figure 2.

The workable equipments and product's varieties and number for due date is given at first. These data means operation model. The inference engine tries to allocate jobs by the planner's selecting allocation methods. The engine will end if all jobs are allocatable. If not allocatable, the engine tries another allocation method as Figure 3. And yet, if not allocatable, the engine resets state previous by one. And the engine will try to allocate by another rules. The engine does repeating such inferences.

	allocate method	key to allocate
1	allocation by arrive time	R_i
2	allocation by job's order number	R_i
3	allocation by shortest processing time	t_{ij}
4	allocation by largest processing time	$-t_{ij}$
5	allocation by due date	D_i
6	allocation by least static slack	$D_i - R_i$
7	allocation by least dynamic slack	$D_i - \sum_{j \in \pi i} t_{ij}$
8	allocation by minimum remainning work time	$\sum_{j \in \pi i} t_{ij}$
9	allocation by maximum remainning work time	$-\sum_{j \in \pi i} t_{ij}$
10	allcation by least slack by a operation number	$(Di - \sum_{j \in \pi i} t_{ij}) / \sum_{\pi i} pi$
11	allocation by most number of operation	$\sum_{j \in \pi i} pi$

R_i : job i's arrive time
t_{ij} : work time to operation j job i
pi : operation number of job i
D_i : due time for job i
πi : Set of remainning openration for job i

Table 1. Solving methods

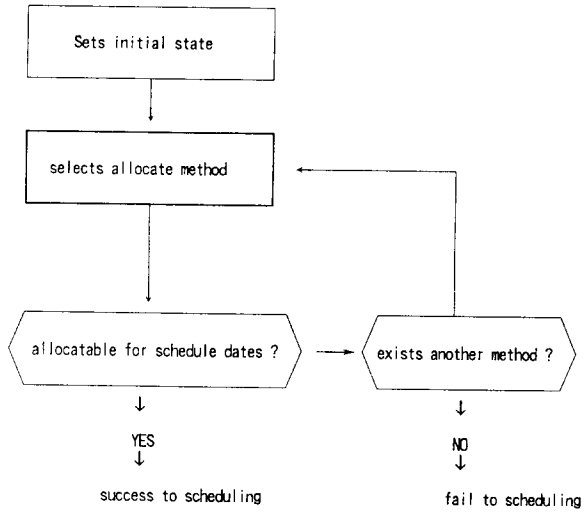

Figure 2. Inference engine Basic flow

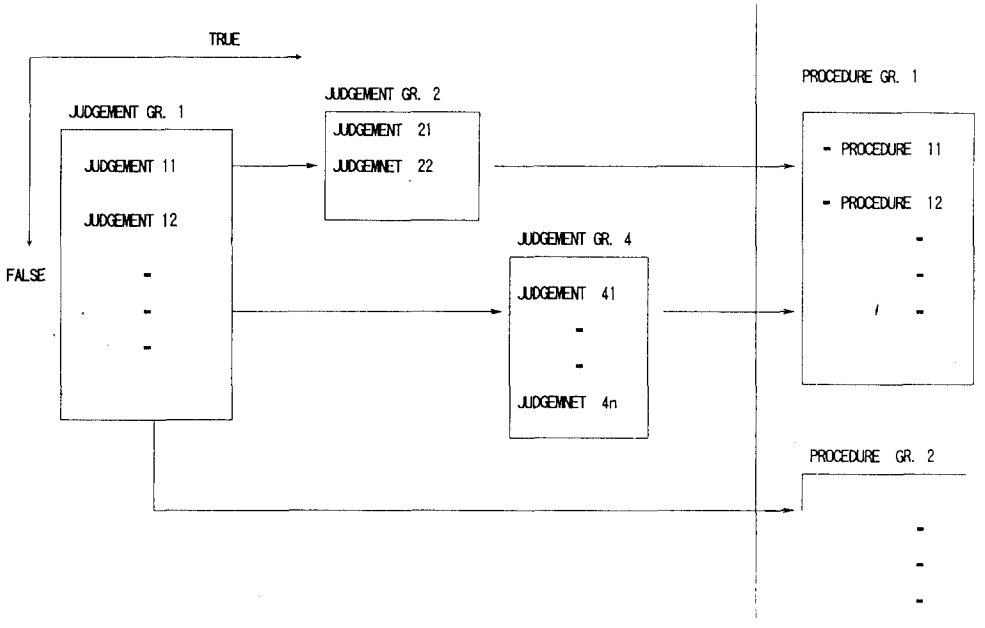

Figure 3. Rule allocation processing

4. Cases by proposal model.

4.1. Application system in assembly process.

In assembly processing industries such as a car, electronic machinery, and tool machines, many varieties and small amount for products is required on manufacturing. It is necessary to establish manufacture system which satisfies to this. In this field, it is important to manage parts composition database correspond to real product lines with constrained conditions. We explain a manufacture control system of the assembly processing line in the automobile industry shown in Figure 4 by our proposal method.

(1) Product model.

This database masters and slaves of products. The information of each part is associated by link structure. The association represents hierarchical structure of the entire parts.

(2) Equipment model.

This database consists of line mutual information among manufacture process, products information on manufacture line, and in-process information on manufacturing.

In this database system, operators can retrieve real proceeding states for line and product with his concern. That is, the database expresses an actual manufacture state that change present in-process and the orders frequently. And by object expression, without rewriting program, operators can reset data, or delete data, or add data if product-model changes.

(3) Manufacture plan.

The number of the parts should be manufactured on each process is calculated for manufacture plan by using database of the manufacture model.

(3) Dispatched order planning.

As for dispatched order planning in each process, it hopes that the manufacture ratio becomes constant. Then it is necessary to be satisfied with the constrained conditions for number of buffers, worker waiting limit time, and the evasion of treatment device shortage, etc. For this, planning method logic is algorithm that adds manufacture engineer's knowhow to levelling equipments use-time.

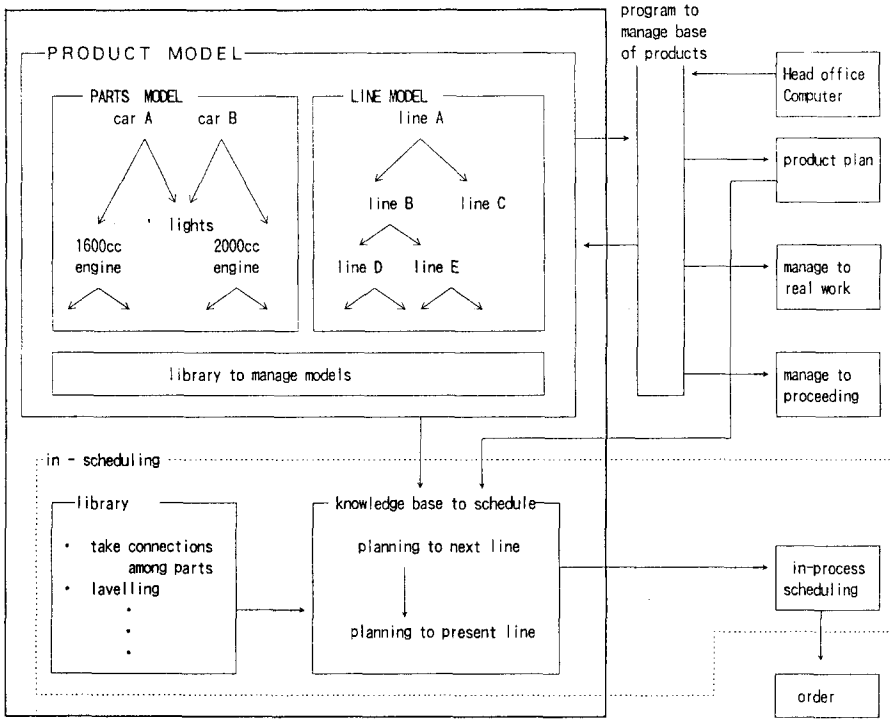

Figure 4. Application system in assembly process

4.2. Application system in piping system process.

In process of piping systems such as chemistry and petroleum, it is a big concern to operate equipments that manufacture maximum products amounts under manufacture plan based on the demand forecast. Old-timer's manufacture engineer was spending time in this work at half a day. Moreover, the equipment has been, frequently changed by demand trend, and he spent much time to maintain database. We describe an off-site plant manufacture computer system of petroleum shown in Figure 5 as an example about the model application of this proposal.

(1) Equipment model.

Equipment of off-site are expressed in a figure called P&I(Piping & Instrumentation Diagram). This P&I is expressed by product model. This represents network model among instruments.

(2) Product model.

Product model represents some conditions for equipments and the job information between the oil kinds.

(3) Scheduling function.

This system is decided by a high-ranking computer and a necessary oil transport work with based on entering port plan, arrival shipment plan, and construction plan on every the day. Then, the system make a solution that do not wait to execute jobs by unusing state of equipments.

(4) Auto line up function.

The auto line up function is to find the operatable line under instruction decided by the scheduling function. And, the instruction to machinery is additionally given.

The object expressed the equipment model, expressed by objects converted into the network expression by nodes and branches. The operatable line is searched in this equipment model by using the graph search technique. The opening and shutting check on the valve not to contaminate will be done at the same time when searching. Moreover, various constrained conditions of the maintenance information of equipments etc. will be checked at this time. The one that these conditions are passed decides the operatable line with the priority order of the change depending on the operation condition.

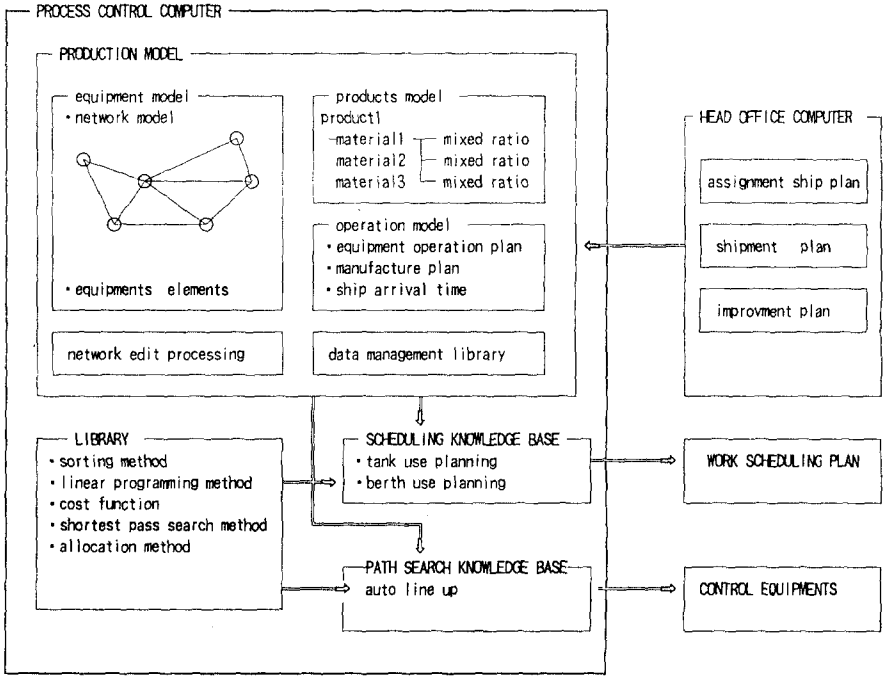

Figure 5. Application system in piping process

5. Conclusion.

Needs of intelligent manufacture system will rise more and more in future. To promote this, it is necessary to research the methodologies for constructing best relation between human and machine. We classify manufacturing model from the viewpoint of operator. The model expression based on object oriented paradigm was proposed in this paper. And we described tool based on our approach. We are applying our approach to real manufacture system.

We propose and try to construct intelligent system which cooperates theoretial optimization OR (Operations Research) technology, model expression technique, data base technology.

6. References

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