Reactive Scheduling by Intelligent DSS

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Abstract. Agile manufacturing is in practice by many companies. In agile manufacturing environments, it is important for companies to make quick response to the changes in the environments. This paper proposes an intelligent decision support system (DSS) for reactive scheduling to handle disturbances in agile manufacturing environments. The intelligent decision support system integrates a knowledge-based system for intelligent and multiple criteria decision-making. The intelligent DSS includes three basic modules, the database module, the model base module, and the interface module. The framework of the intelligent DSS is presented. The objective-oriented data model, the knowledge-based rules, and rule induction are designed. The reactive scheduling algorithm is developed. Radio frequency identification and knowledge acquisition tools are applied by the intelligent DSS. The intelligent DSS can be implemented by applying contemporary information technology and can provide an approach to make reactive production scheduling decisions quickly to handle disturbances for manufacturing firms to obtain competitive advantage and agility.

Keywords: Reactive Scheduling, Multi-criteria Decision Making, Decision Support System, Inductive Learning, Knowledge-based System, Agile Manufacturing.

1 Introduction

Agile manufacturing provides a new way for new challenges and wants companies to react quickly to customer demands and market changes [1]. In manufacturing and supply chain environments, disturbances may occur, such as a machine failure, job priority changes, unavailable materials, and so forth [2,3]. Therefore, companies have to react quickly to environment changes to obtain competitive advantage and agility.

This paper considers a production scheduling problem with disturbances in agile manufacturing environments. The shop floor contains multiple resources to produce orders. The suitability and availability of the resources are not guaranteed. Disturbances occur in the shop floor and reactive scheduling is applied. An intelligent DSS is proposed. The approach applies the technology of database and knowledge base.

Researchers have studied reactive scheduling. For example, Du and Chiou [2] proposed a reactive scheduling architecture based on objective-oriented database technology. They applied version management of an object-oriented database, demonstrated the different types strategies for reactive scheduling, and considered two types of unexpected events.

Sauer [4] studied vertical data integration that used data from a shop floor. The vertical data integration was made for scheduling decisions on higher levels so as to support reactive scheduling in supply chains.

Paprocka and Skołud [3] proposed a hybrid multi-objective immune algorithm for predictive and reactive scheduling. Their approach applied heuristics to minimize the impact of disrupted operations on scheduling. Their approach considered and predicted time of failure and used maintenance work into a schedule.

2 Intelligent DSS for Reactive Scheduling

Agile manufacturing is in practice by many companies. Information technology is suggested for agile manufacturing practices to obtain competitive advantage and agility [5].

The decision support system (DSS) is part of information technology/information system and mainly contains a database management system, a model base system, and a user interface system [6]. An decision support system can support decision-making in many situations such as production planning, inventory control, and so forth [6].

The knowledge-based system (KBS) has been employed in computer-based decision-making. Two primary approaches utilizing KBSs are the use of KBSs directly as a type of DSSs and the integration of KBSs with conventional DSSs [7].

In this paper, an intelligent decision support system is proposed for reactive scheduling in agile manufacturing environments. The intelligent DSS integrates a knowledge-based system to make intelligent decisions. Customers and the shop floor are in the Internet environments. The intelligent DSS includes mainly three modules, the database module, the model base module, and the interface module.

The architecture of the intelligent DSS is illustrated in Fig. 1. RFID technology is the significant advance in managing dynamic systems, which contains the components of tags attached to the objects to be identified [8]. Tools in the DSS includes knowledge acquisition tools, RFID tag identification tools, FRID information processing tools, and other tools. Services include web servers, DNS servers, ONS servers, database servers, and other servers.

3 Components in Intelligent DSS

3.1 Object-oriented Data Model

Object-oriented database technology has been applied in reactive scheduling [2]. An object-oriented data model is developed for the database model of the intelligent DSS.

Fig. 2 shows the object-oriented data model. In the figure, primary and foreign keys of an entity are expressed by underlines and stars, respectively. A crow's foot is used to express one to many relationships. Optional and mandatory relationships are expressed by circles and bars, respectively [9].

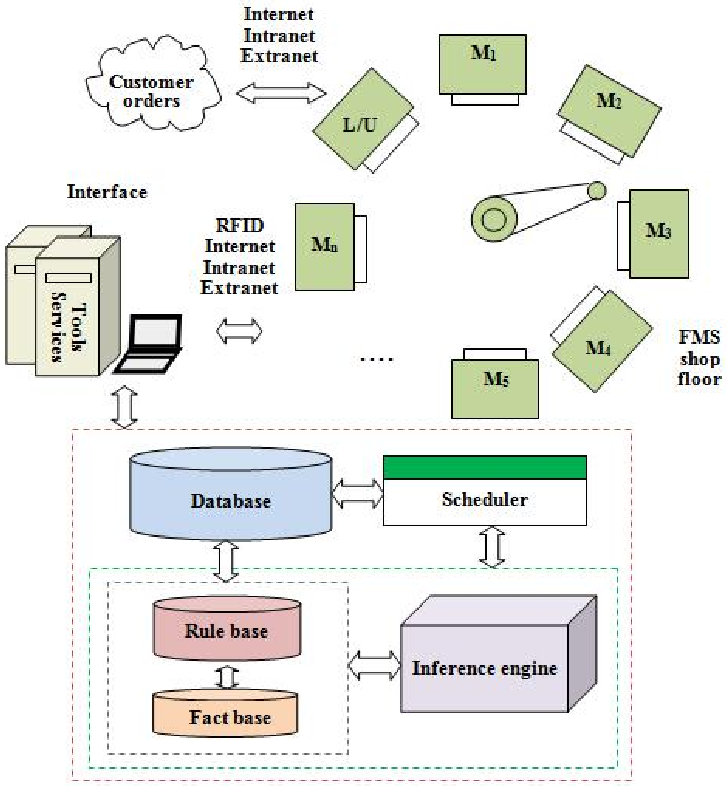

Fig. 1. Architecture of the intelligent DSS.

3.2 Reactive Rules

The rule base, fact base, and inference engine are designed for the model management module. Researchers have considered disturbances in shop floor such as machine breakdowns, lack of materials, and so forth [2,3]. The disturbances considered are newly added machines, machine breakdowns, and rushed orders. Knowledge-based rules are developed to handle disturbances.

The production scheduling problem is a multiple criteria decision-making (MCDM) problem. A additive utility function is applied [10]. Notation used to describe the rules is listed in Table 1. The rules developed in the rule base include the following.

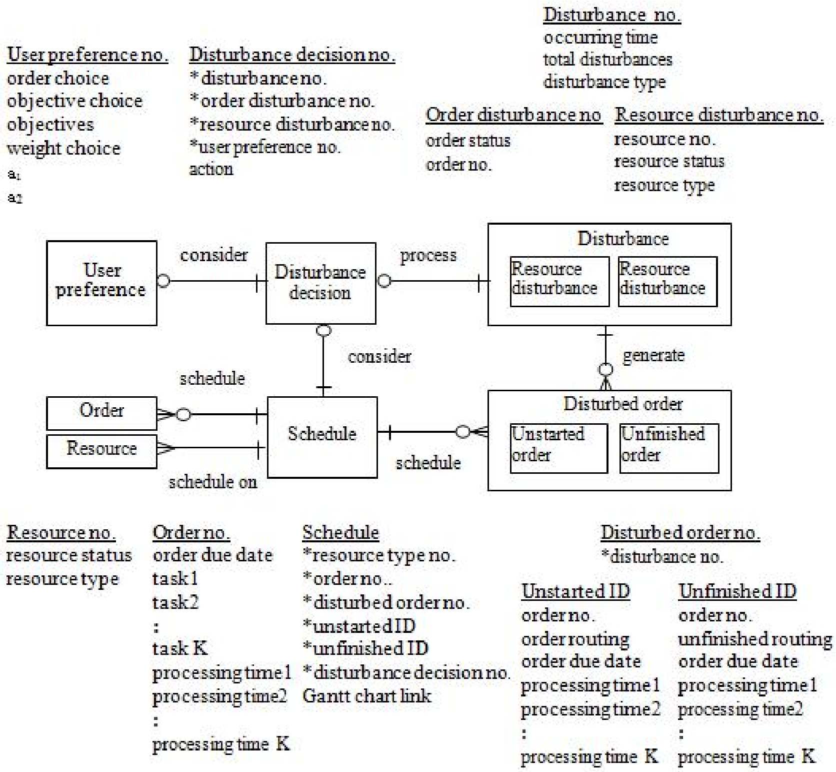

Fig. 2. Object-oriented data model.

Table 1. Notation for rules.

Symbol	Description
d	Disturbance type, $d \in \{added, broken, rushed\}$
t_n	Total disturbances
f_o	Total orders finished
s	System status, $s \in \{no, new\}$
m	Manager, $m \in \{no, new\}$
o	order, $o \in \{0,1\}$
r	Resource, $r \in \{0,1\}$
c	Weight choice, $c \in \{user, system\}$
U	Additive utility function
$u_1(x_1)$	Utility function 1
$u_2(x_2)$	Utility function 2
a_1	Weight for $u_1(x_1)$
a_2	Weight for $u_2(x_2)$

Rule 1. If $\mathrm{m} = \{no\} \rightarrow \mathrm{s} = \{no\}$;
Rule 2. If $\mathrm{t_n} \geq 4$ and $\mathrm{m} = \{new\} \rightarrow \mathrm{s} = \{new\}$;
Rule 3. If $f_o \geq 90\%$ and $m = \{new\} \rightarrow s = \{new\}$;
Rule 4. If $\mathrm{t_n} \geq 4 \rightarrow \mathrm{s} = \{no\}$;
Rule 5. If $f_o \geq 90\% \rightarrow s = \{no\}$;
Rule 6. If $t_n < 4$ and $f_o < 90\% \rightarrow s = \{new\}$;
Rule 7. If $d = \{added\} \rightarrow r = \{1\}$;
Rule 8. If $d = \{broken\} \rightarrow r = \{0\}$;
Rule 9. If $d = \{rushed\} \rightarrow o = \{1\}$;
Rule 10. If $c = \{user\} \rightarrow$ obtain a_1 and a_2 from a user;
Rule 11. If $a_1 \neq 0$ and $a_2 \neq 0 \rightarrow U = a_1u_1(x_1) + a_2u_2(x_2)$;
Rule 12. If $a_1 \neq 0$ and $a_2 = 0 \rightarrow U = a_1u_1(x_1)$;
Rule 13. If $a_1 = 0$ and $a_2 \neq 0 \rightarrow U = a_2u_2(x_2)$.

The system status and manager can be one parameter in the set of 'no' and 'new'. The 'no' means not to change the current schedule. The 'new' means to change the current schedule to a new schedule. For example, if $f_o \geq 90\%$ and $m = \{new\}$ in Rule 3. The rule gives the status of the shop floor with the total orders finished are larger than 90% and the manager decides to change to a new schedule. This rule results in the formulation of a new schedule by the system when the status occurs. When a disturbance occurs, the status of the shop floor is monitored and checked. The DSS can apply the rules to result in appropriate decisions.

3.3 Rule Induction

Rule induction is conducted in handling disturbances in the inference engine. Inductive learning ability is designed. The mechanism of rule induction is illustrated in Fig. 3. First, the fact base and the rule base are formed. The next step is the reasoning recurrence of resolving facts to obtain sub-facts, matching facts to obtain candidate rules, and matching rules to obtain candidate facts. If there are disturbances in the shop floor, the fact base is automatically updated. After the reasoning recurrence is accomplished, the rule base is automatically updated.

4 Reactive Scheduling Algorithm

The production scheduling problem is an MCDM problem. The additive utility function is applied to the problem as stated before. The objective of the problem is described in the following. Symbols used are provided in Table 1.

$$\text{Min} \quad U = a_1u_1(x_1) + a_2u_2(x_2) \qquad (1)$$

$$0 \leq a_1 \leq 1,\ 0 \leq a_2 \leq 1,\ a_1 + a_2 = 1.$$

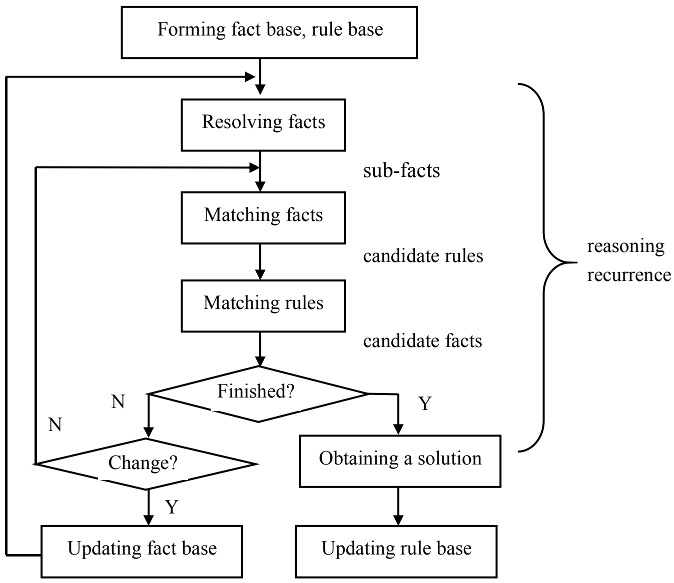

Fig. 3. Mechanism of rule induction.

The reactive scheduling algorithm is developed. Resources are used to perform a group of tasks which belong to manufacturing orders having their processing routings, processing times, and due dates. Symbols used in the algorithm are described in Table 2. The pseudo code of the algorithm is presented in the following.

Table 2. Symbol for algorithm.

Symbol	Description
i'	Resource type
I'	Total resource types
k	Operation
K	Total operations
j	Order
i	Resource
$\emptyset$	Empty set
t_m	Temporary storage
t_r	Temporary storage

Reactive Scheduling Algorithm

$i' \leftarrow 1$;
$k \leftarrow 1$;
while $k < K$ do
 $t_m \leftarrow$ orders of operation k;
  while $i' < I$ do
  $t_r \leftarrow$ orders $\in t_m$ and to be assigned to resource type i';
   while $t_r \neq \emptyset$ do
   $j \leftarrow$ orders $\in t_r$ and having minimal U by Equation (1);
   $i \leftarrow$ resource having the same type of i' and having the earliest available time;
   assign j to i;
   remove j from t_r;
   remove j from t_m;
   end
  $i' = i' + 1$;
  end
$k = k + 1$;
end

The algorithm is to make new schedules immediately and continuously according to current situations of the shop floor. The information such as disturbance occurring times and other relevant data can be obtained through a monitoring system. The DSS processes these information and other information to analyze the status of the shop floor. The monitoring system can utilize information technology such as RFID that is the significant advance in managing dynamic systems as described before.

In the intelligent DSS, the algorithm, the knowledge-based rules, the inference engine work together to make intelligent decisions for handling disturbances. The reactive rules are applied by the DSS to make decisions on if a new schedule needs to be developed or not. The rules are updated after disturbances occur. Once the DSS makes a decision of formulating a new schedule, this reactive algorithm is applied to make a new schedule.

5 Conclusion

This paper proposes an intelligent DSS for reactive scheduling to handle disturbances in agile manufacturing environments. The proposed approach applies information technology, which is different from many traditional production scheduling approaches. The objective-oriented data model, the knowledge-based rules, and the rule induction mechanism are designed. The reactive scheduling algorithm is developed.

In agile manufacturing environments, it is important for manufacturing firms to react quickly in the changing environments for agility. The intelligent DSS can be implemented by applying contemporary information technology. It could provide an approach for reactive scheduling to handle disturbances for manufacturing firms to obtain competitive advantage and agility.

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