Solving the Modules Interaction Problem in MES Platform Based on Production Process Event Model

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Abstract: In the manufacturing execution system (Manufacture Execution System, MES), configurability, reconfiguration, expansibility has always been one of the difficulties to be solved. In this paper we present an integrated platform for configurable event-triggered rules base and real-time message queue engine service based on adaptive QoS (Quality of Service, QoS) publish / subscribe. Through the event-triggered rule base management, configures event-triggered rule in different business processes, to implement event-based production process models describe the actuality productions. We use publish / subscribe service model for a large number of mechanisms to achieve real-time event handling message passing, and complete a mount of bottom-up information collection and processing. And tests proved that, performance of MES platform is improved.

Keywords: MES; configurable; model; event; integrated platform; message queue.

Reference: to this paper should be made as follows: Shuo Lin, Haibo Shi, Xisheng Lv and Zhonghua Han (xxxx) ‘Application Research of Event Based Model on Configurable Integrated Platform’, Int. J. Modelling, Identification and Control, Vol. x, No. x, pp. xxx-xxx.

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1 Introduction

In recent years, MES as a system faced workshop for production process management and real-time information management, mainly solves the implementation of the workshop production tasks, and contact the production planning and industrial control (White Paper Number 16, 2005; Andress Sehmunna, 1997). Compared with foreign countries’ MES, most of domestic MES products are poor, they mainly based on the actual needs of the factory to customize. Most business processes and descriptions are cured by the codes, so they can not achieve the reuse within the business. And there is a development of high cost and long implementation cycle problems.

From the business perspective, petrochemical, metallurgical industry, on behalf of flow and mixed Industry is turning into a new generation which manufacturing process can be recycled. It mainly refers that, in the manufacturing process of flow industry, energy, waste can be recycled. To achieve this goal, it requires not only advanced manufacturing ideas, equipments, technologies, but also the support of information technology platform. Research and development the configurable MES solutions and products for the business, improvement the ability to adapt to continuous of business process are significant. Based on researching and developing the configurable MES solutions and products, the improvements of abilities to adapt to continuous business processes are significant.

Many people do research on the production process model and platform, as shown below. Qin and Xu (Qin and Xu, 2010) construct an intelligent information system of an assembly line in a network-based collaborative manufacturing environment. Chen and Chen (Chen and Chen, 2010) propose an event diffuse model EDM which was proposed to dig out sensitive information of the event from the relevance of bottom elements and main objects of events. Tyson (Tyson et al., 2006) provides a foundation for modeling the set of activities and their relationships by which systems are engineered, or, more broadly, by which products and services are developed. Miao (Miao et al., 2010) introduces an event-driven simulation framework which is flexible to reorganize the different models and easily extended to distributed system. Kemper and Tepper (Kemper and Tepper, 2009) describe a novel technique that helps a modeller gain insight into the dynamic behaviour of a complex stochastic discrete event simulation model based on trace analysis. Wang (Wang et al., 2012) establishes a model of shipboard power system and reconfigure the model. Wang and Xiong (Wang and Xiong, 2010) proposes a models for high performance real-time detecting and tracking technology for news events. A fuzzy discrete event system is proposed by Li (Li et al., 2009). Zhang (Zhang et al., 2003) propose and design a real-time event scheduling model which is based on the priority of events for BCEPS system and it can improve our research on event priority level.

For the type event model of production process, there are some good ideas. Bryce (Bryce et al., 2011) study on Event-Driven Software and evolve the model. Kwong and Yonge-Mallo (Kwong and Yonge-Mallo, 2011) give an incomplete model of the discrete-event system and address the problems of diagnosing fault. An intelligence model in man-machine systems is proposed by Riad (Riad et al., 2012). Tkachuk and Dwyer (Tkachuk and Dwyer, 2010) study on Event-Driven system and focus on developing broadly applicable mechanisms for modeling environment behaviors. Wang (Wang et al., 2009) proposes a dual-center event model to improve the event tracking process by adjust the some attributes of event dynamically. Xu (Xu et al., 2009) presents an event model adapted for representing the event connotation, the extension and the relation between them. Xiong (Xiong et al., 2010) analyse the discrete event generation model and get the test result of network simulation. Zhang (Zhang et al., 2009) provides an event model for defining sophisticated conclusions as post defined complex events, and provides a task assigning mechanism and a data gathering mechanism for collecting these complex events through the cooperation of the hierarchically organized delegate nodes. Gong (Gong et al., 2010) discusses a standard specification and an extensible interface of a model of simulation events and their triggers in Web-based discrete event simulation called TEA-XML (Triggers and Events Association XML).
2 Framework of Configurable Integrated platform

3.1 Issues of MES

Because our research on MES is late, so compared with foreign products, we have the big gap and lots of matters. Due to lack of a unified plant data model, among the various functional subsystems and between the MES and other enterprise information systems, we are lack of necessary integration, which led to MES as the engine of manufacturing collaboration is far from being fully functional. MES as a manufacturing plant for real-time information system, real-time is the basis to achieve functions. Existing systems are lack of accurate, timely and complete data acquisition and information feedback mechanism, in the underlying real-time data acquisition, multi-source information fusion, and complex information processing and rapid decision-making is very weak. Existing system is usually for a specific need and difficult to cope with the changes in business processes or the restructuring. Due to lack of integration technology which based on plant data model data, absence of configurability, reconfiguration and expansibility restricts the promoting of MES.

3.2 Framework of Configurable Integrated platform

To solve the above problems, analyzed the characteristics and relevancies of production process events, we presents an integrated platform for based event-triggered rule base and based publish/subscribe real-time message queue engine service based on event-based production process models, as shown in Figure 1 below. We achieved system integration of real-time communication and real-time data acquisition, to support construction configurable process industry MES solutions and software products.

The framework of an integrated platform composed mainly by the following:

1) Event-Based production process model: MES platform production process modeling reflect the actual production status, the production process event model is the most important point. The main purposes of establishing the model are as follows. First, using vivid and unified language describes the process, and as a basis for the exchange to promote understanding and communication. Second, establish the formal definition of process to use scientific methods to support process analysis and improvement. Third, utilize computer-aided tools to achieve production process automation of operation, management and monitoring. Forth, achieve the mapping from production process to software system to make the software system satisfy the production demand and adapt to production changes, and can adjust reasonably. The Production Process Architecture Based on Event is shown in figure 2 below.

2) Event-triggered rule base: Store integrated event-triggered rules, including basic rules, general rules, and trade rules.

3) Based publish/subscribe real-time message queue engine: Adopt based publish/subscribe process framework, and message scheduling and notification mechanism use adaptive QoS real-time publish/subscribe mechanism, through reflection (Reflection) mechanism, it creates a plug mode. It allows the system to dynamically load components, and enable the system to change its function in run-time to enhance the flexibility of the system.
event relations and trigger rules of the production process event model are the most important problems which need to be resolved. The relationship between them is as shown in figure 3 below.

![Production process event model](image)

**Table 3** Production Process Event Model Relation Diagram

We defined the production process events as follows: The events of the production process (hereinafter called as Event) is an abstract description of the production activities in the manufacturing process, is the most basic elements to describe the production system. It can be a production operation and can also be a parameter to modify.

Production event: Events generated in the production process are called the production event. Production events of the model are the abstraction of the actual production process events, including all the properties of the events.

Properties of the event: It’s an abstract description of event particular characteristics in actual production process. Production event usually have some properties, and these properties constitute the attribute set of the production event. The properties can be extended depending on the application. The properties of events are to make event status, determine the relationship between events, and improve the model expression.

Element event: The element event is the smallest unit of logical division of the production event. All the production events are composed by one or some element events.

Decomposition of production process: When the production plan is assigned, for different products, it can produce some production process according to different production process. The process can explain that the workers should do which operate in the production process. Every production process can be an independent production event.

Events trigger rules: when the production is processing, it can generate production events. If the event can trigger another event, we can say that under some trigger rules, the event is the precursor event of the follow event, and they has a trigger rule to trigger the follow.

There are some important properties in event model, for example event Id, event status, event level, production plan (plan number), product information (product number, production order number), device information (work unit Id, production line Id), time information (production time, time stamp), material information (lack material, waste material), plan or production priority level, and so on. After expanding these properties, we can describe the production process, and the event status can be used to control the dead line of event. We use attribute set of properties to express any properties of element event. If the attribute set of properties is the element property. In the attribute set of properties, the properties can expanded and improved according to the production demand or actual production.

The event is an abstract description of the production activities in the manufacturing process and the most basic elements to describe the production system. The dynamic process of the production system is driven by events. The changes of one or a series of data labels are the trigger condition of the actual events generation. Some events are about time, so time is one of a trigger condition. There are some trigger rules between the production events. Production events and trigger rules compose production process event model, and the model is also the execution model.

The relationship set between events have three type, they are precursor events set, follow events set and events backtracking. The precursor events set is that current event is activated or processed by the events of precursor events set. The follow events set is a new set which is generated by the activated or processed current event. An event backtracking is a process of backtracking according to the precursor events set and follow events set. We can get the process of event generation, and can follow the track of production process according to events.
is triggered by the event of the precursor events set. Time / period trigger means that the event is triggered in a time or in a cycle. A simple relation of trigger between events is shown in figure 4.

4 Event-triggered rules base

For the needs of configuration integrated platform, existing methods cannot guarantee that members of the initiative and the timeliness in the integration process. In this paper, we present an integration approach based event-triggered rules, it can introduce event-triggered rules with active service into the integrated platform. We studied how effective use of event-triggered rules to express event handling process, how to design data integration system framework based on event-triggered rules, achieved by the mechanisms of event-triggered rules to ensure the data integration process and timeliness and initiative. Event-triggered rules based integration framework is shown in Figure 5.

![Integration Framework](image)

**Table 5** Event-triggered rules based integration framework

The event-triggered rules based integration framework composed mainly by the following.

1) **Event-triggered rules base**: Store the rules set by user according to their needs. The storage manager of rules is for the definition, modification, and access of the rules. Parser access rules are based through storage manager of rules, to configure the rules, and initialize the system when it startup.

2) **Parser**: Parse the rules stored in rules base into an executable conditional expression and task list, and then put the results into the rule parse tree unit.

3) **Rule parse tree unit**: Store the executable conditional expression and task list which parsed by parser.

4) **Service Engine of real-time message queue**: Through based publish/subscribe real-time message queue engine, it accesses data and monitor system running in real-time, and send to event trigger the notices of business needs changing when it detects the changes of data and business.

5) **Event trigger**: When receiving a notice, extract corresponding conditional expression and task list from the rule parse tree, then send to event handling executor.

6) **Event handling executor**: Analyze the validity of conditional expression receiving from event trigger, if it's available, then it executes the task in the list and get the result. Event handling executor has two parts, one is validity of the event request analyzer, and the other is event handling executor. Validity of the event request analyzer calculates the conditional expression after receiving a conditional expression and task list. If the result is true, it sends the task list to event handling executor. Event handling executor performs the each task in the list and calculates for the results of the event processing after receiving task list.

In practice, by the definition of event handling process rules, we separate the business logic and technical support, and separate the business function and plant model, which can support the sustainable improvement of business processes, continuously update in different industries, different fields, and changes of system function module.

4 Real-time message queue engine service based on adaptive Qos publish/subscribe

The biggest advantage of message publish/subscribe model is that communication is a loosely coupled relationship between entities. It achieves the synchronism independence of the distributed interaction, meeting the system integration needs in distributed and heterogeneous environments. System structure is shown in the figure 6.

![Event Notification Service](image)

**Table 6** Event notification services based on publish/subscribe.

Considering the limited timeline and requirements of the integration applications of production process to provide timely response, and the resources of applications are limited, it leads the priority of most integration services with the clients are different. So we adopt QoS guarantee mechanism to ensure the order, integrity and real-time of integration.

The processes of Adaptive Qos-based publish/subscribe real-time services as follow.

1) Application generates a request with the QoS (sub).
2) QoS negotiate and process the requests of incoming; if it meets the needs of QoS (max), then generate the parameters which make the service satisfy the needs of QoS, and logging in Qos manager.

3) QoS monitoring is initiated by the application or in a regular time, Qos monitor will compare Qos (active) with Qos (sub) stored in Qos.

4) According to the disparity of Qos (active) and Qos (sub), adjustment the scheduling policy of Qos.

5) Adjust the publish/subscribe service parameters.

After the message subscriber submits the quality of service required, system will find the quality of service in QoS service manager that current system can provide, and then compares the two service qualities. If the qualities of services provided meet the current needs of users, it maintains the existing system. Otherwise, it will submit the current available quality of services to the service needs of those; users decide whether to accept the current situation. If the quality of existing services is acceptable, maintain the existing system, otherwise, modify the existing system to meet the users’ requirements.

Based on Adaptive Qos publish/subscribe real-time services mechanism, we design a real-time message queue service engine. We call an example with full Network. A Network has lots of different nodes. These nodes are running on different hosts in the Host Process. Each node contains one or more pipelines; a pipeline contains one or more Handler. Handler is the basic processing module. Figure 7 shows the basic structure of based on adaptive Qos publish/subscribe real-time services engine.

The Host Process based on adaptive Qos publish/subscribe real-time services engine is designed to execute and manage one or more example of Nodes to make full use of the computing power of host computer. Host Process does not directly interpose the processing logic in the Node, but can manage to create or remove Nodes. When the Host Process receives a control message, it is automatically configured according to the message and starts the corresponding Node, and load specific modules for them. These modules may be located in an accessible network location. Through spreading a control message in system, we can change the behavior of Nodes online.

The components of based on adaptive Qos publish/subscribe real-time services engine are shown as follow.

1) Node: Node is the logic unit of based on adaptive Qos publish/subscribe real-time services engine. Each Node contains a complete logic function, which is an autonomous message processing unit. Node is the entity of logic. Details of the internal structure or implementation details of the node are cannot be learned by the other nodes or external environment. When system running, it exists more examples of same Node in one or more computer. Node receives message based on adaptive Qos publish/subscribe real-time services engine. After processing the messages, it produces one or more message and sends out to the specific Node. Nodes are independent from each other, exchanges information by message. There are three parts in Nodes, they are message dispatcher, processing pipeline, output routing. Message dispatcher retrieves the properties of message by retrieving XQuery, matching the different conditions, distribute the message corresponds to one or more pipeline to process. Processing pipeline processes the message and put the messages to routing module. Routing module retrieves the properties of the message, forwards message to a different destination according to its property.

In the Node based on adaptive Qos publish/subscribe real-time services engine, it adopt the chain of responsibility model as a basic framework for message processing. The chain of responsibility model has very good flexibility and scalability, it links? With different functional modules, and the processing requests transmit in the chain. System can reorganize the chain of distribution of responsibilities without prejudice to the case of the client.

Based on adaptive Qos publish/subscribe real-time services engine organize the chain of responsibility with Pipeline. Each Pipeline contains a Header, a Tail and some Handles. Header is responsible for receiving messages, and sends to the Handler to proceed. Each Handler has a separated processing logic, which sends message to next Handler after processing. The last Handler sends message to the Tail after processing, and the Tail exports the message.

2) Message exchange based on contact: Based on adaptive Qos publish/subscribe real-time services engine use the Message exchange based on contact, this approach is not limited to the specific format of the message, as long as the message sender and the receiver can understand each other. The engines all use the XML message format for data exchange between internal nodes and between external applications.

3) Transmission mode based on the adapter: Based on adaptive Qos publish/subscribe real-time services engine use adapter mode to support different transmission. Adapter mode package different communication protocols as a uniform interface, system enable the interface to support the corresponding transport protocol. The adapter of based on adaptive Qos publish/subscribe real-time services engine supports TCP, UDP, HTTP and MSMQ (Microsoft Message Queue).

4) Message routing mechanism: Based on adaptive Qos publish/subscribe real-time services engine contains whole message routing mechanism. By the mechanism, messages can be transmitted to different nodes by different protocols. Message routing mechanism mainly includes the address defined and forwarding rule in two parts. Based on adaptive Qos publish/subscribe real-time services engine locate a Node with the format like <protocol: Network/Node>. Address not only includes the location of the Node, the default transport protocol, may also contain additional information such as the verification code of the Node. Forwarding rules define how to send messages for different purposes. In many cases, the message sent to the specified node may take the necessary intermediate processing Node, forwarding rule specifies how these messages are sent. Particularly, the forwarding rules also include the treatment strategy when the destination Node can’t reach. There are
typical strategies such as forward the message to backup processing nodes or storage to the dead letter queue temporarily.

As mentioned before, function module of Node is loaded according to the configuration by the Host Node. These modules can be located on the local or any location of network, which provide the system with a high degree of flexibility. By using the adapter mode and the reflection of platform, we can integrate any third party application component or any new components based on business needs into the service engine. As a result of reflection, the function module does not need to follow strict interface specification, as long as they can exchange messages serialized in XML format.

On the other hand, based on adaptive Qos publish/subscribe real-time services engine contain some basic modules to support establishing a publish/subscribe system, such as Qos control module, Message encryption / decryption module, Web Service call module, Cache module, Log module, Event module.

Through these basic modules, we can achieve the configurable of the integration platform in the framework of based on adaptive Qos publish/subscribe real-time services engine. We can increase new modules or remove unnecessary modules at any time to meet the new demands.

### Table 7

| Basic structure of Based on adaptive Qos publish/subscribe real-time services engine. |

5 Concluding remarks and future work

In this paper, we present an integrated platform for event-triggered rules base and real-time message queue engine service based on adaptive Qos publish / subscribe. It integrates the event trigger rules from event-based production process models, and is configured according to business and production process and can adjust quickly once the production process needs change or restructuring to raise configurability, reconfiguration and expansibility of MES. The real-time message queue engine service based on adaptive Qos publish / subscribe can handle lots of event processing information from production process and adjust dynamically to satisfy the demands of production. We can apply new modules or remove unnecessary modules at any time to adapt to the new demands of MES to increase configurability.

By the testing to the platform, its responding time reaches a minute level, and the platform has the ability of practical application. But compared with foreign products in developed countries, there are still some shortcomings. When the events increased significantly, the platform’s performance comes down very obviously.

As indicated in the table, with the number of unit increasing, the corresponding tags which can trigger events are increased, and the response time is longer. So we will do some research on this problem, and improve the algorithm of event process to improve the responding time.

### Table 1

<table>
<thead>
<tr>
<th>Number of units and tags</th>
<th>Response time of client</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 units, 100 tags</td>
<td>10s</td>
</tr>
<tr>
<td>100 units, 500 tags</td>
<td>20s</td>
</tr>
<tr>
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<td>90s</td>
</tr>
<tr>
<td>500 units, 3000 tags</td>
<td>160s</td>
</tr>
<tr>
<td>2000 units, 10000 tags</td>
<td>580s</td>
</tr>
</tbody>
</table>

Acknowledgement

The authors acknowledge the financial support of the National High Technology Research and Development Program 863-Program Foundation of China under Grant No. 2011ZX02507-006, and Scientific and technological project in Liaoning Province (2010020068-201). The authors would also like to acknowledge the helpful comments and suggestions of the SIA-MES software group. Their efforts are greatly appreciated.
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