A web-based reconfigurable shop floor control system

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ABSTRACT: A reconfigurable shop floor control system based on components is introduced, related shop floor model framework, modeling method, system architecture, and components design are introduced, and system primary design technique as system structure, components partition and XML application are described. The system designed has been used to control two different types of shop floors in a machine tool company, which is configurable, scalable and reusable.

1 GENERAL INSTRUCTIONS

Workshop is a complex system, variable market requirements, technology progress and changed business rules request the agile shop floor control system (Choi 1997). The shop floor control system must be reconfigurable to adapt the dynamic, variable environment. Reconfiguration will allow adding, removing, or modifying specific process capabilities, controls, software, or machine structures to adjust production capacity in response to changing market demands or technologies (Mehrabii, et al 2002). A reconfigurable shop floor control system should be scalable, configurable and reusable.

The reconfigurable shop floor control system must face initiative changes and passive changes of the manufacturing system. Initiative changes refer to system initatively update elements and adjust subsystem to change functions. Passive changes refer to changes arose by unknown disturbs (such as equipment failure, material shortage, system lock, etc.) (Mehrabii, et al 2000). Reconfigurable shop floor control system responses to these changes by static reconfigure and dynamic reconfigure. Dynamic reconfigure means that system evolves steadily and develops stably as environment transform stably or business change can be forecast at long-range, and static reconfigure means that system regroup thoroughly as environment transform drastically or business change cannot be estimated.

The article introduced a reconfigurable shop floor control system designed, a system modeling approaches by the complementary use of IDEF and UML is adopted. The remainder of this paper is organized as follows. Section 2 presents the overall structure of the system, and related system modeling methods, and each module's primary element and its function are expounded. Section 3 discusses the system architecture designed by applying the method based on B/S (Browser/Server) and Windows DNA (Windows Distributing Internet Application Architecture). Section 4 reports on our efforts to design system components, and component partition rules are sum up. Section 5 presents and discusses XML technology applied in the system design. Finally, Section 6 summarizes the favorable results gained from the design.

2 MODELING FRAMEWORKE

Fig.1 shows shop floor modeling framework for reconfiguration. The framework includes five parts: business process model, organization model, function model, data model, and object model. Business process model is business activities chain composed of series shop floor activities, which describes business process activities and relation between activities. Organization model includes organization model and process organize model, which describes organize mode and its work mechanism. Function model describes shop floor functions or systems functions, relations between functions, and datum support functions integration. Data model describes system information and their relations, catch logic relations between shop floor data. Object model is used in require analysis, system design, system testing, and the like during system development.

Shop floor business process reconfiguration, organization reconfiguration, and information reconfiguration rely on each other with compact relations. Reconfigurable system design is based on analysis
their relation. Business reconfiguration is the foundation of information system reconfiguration, and information system reconfiguration will also impact organization structure and organization process. Literature (Shang 2004b) gives approach to build reconfigurable shop floor model framework. The article will introduced information modeling gained from the shop floor model framework as follows.

![Reconfigurable Shop floor modeling framework](image)

**Fig.1. Reconfigurable Shop floor modeling framework**

### 3 SYSTEM STRUCTURE

A method of modeling the information system with the complementary use of IDEF and UML was studied. The IDEF0 method is used to specify the information requirements, the IDEF1x models support modeling a relational database and the UML models aid to design object-oriented software (Shang 2004a).

Fig.2 shows system general structure. The reconfigurable shop floor control system includes six modules: organization and personnel manage, process planning and design, production planning and scheduling, manufacture resources manage, production control and quality manage, statistic and synthetic query.

The system primary input information include organization and employee info, enterprise MRPPII, material inventory, client info and other systems info; primary output information include produce arranged info, material requirements, manufactured product, produce statistic info; primary control information include management system, design drawings and technical documents, production planning and scheduling rules, resources configure strategy, quality guarantee system; primary sustain include reconfigurable software system technique, shop floor technical stuff, production manage stuff and quality manage persons.

Organization and personnel manage includes personnel file manage, personnel on duty record, personnel assess, organization and institution, and coding maintenance, etc. This module provides exact and timely human resources info for the managers.

Process planning and design includes process design, files manage, numerical control program, BOM, etc. Technicians can manage process files, numerical control program, and product structures by these functions.

Production planning and scheduling includes shop floor production planning, shop floor parts planning, shop floor material requirement planning, basal datum, product delivery, man-hour complete, work-in-process stat, production task, and shift planning control. Accordingly, production managers can organize production by accurate workshop section and shift planning.

Manufacture resources manage includes stock parameters, stock account, stock check, equipment account, and equipment maintain. Stock management controls the storehouse roundly by the mode of assort and classification. Equipment management provides equipment capability and status for other subsystems.

Production control and quality manage includes process course control, working procedure quality, quality planning, quality cost, and quality cost assess. This module provides accurate, general process course and quality datum for the managers.

Statistic and synthetic query includes man-hour stat, production stat, process datum query, parts quality stat, etc. By this module, shop floor managers can obtain production datum, equipment usage, manufacture status and process info.

![System IDEF0 function model](image)

**Fig.2. System IDEF0 function model**

### 4 SYSTEM ARCHITECTURE

The system architecture is designed by applying the method based on B/S and Windows DNA, with three-tiers: presentation, business logic and data, so the system can be reusable and scalable (Sten & Per 2000).

Fig.3 shows the reconfigurable shop floor control system architecture, Web application client-side forms presentation layer; web server, application server composing business logic layer, and data-base
server constitutes data layer. Presentation layer serves by mutual with users, includes graphic user interface, and all the display logic, such as Windows interface, DHTML and ASP, etc. Business logic layer includes all the business rules, and business logic. Data layer includes data access engine (like ADO, OLE DB), special data base system, etc.

Business logic layer can be divided into facade components, primary business components, and data access components, they separately provide facade service, primary business service, and data access service. Facade component objects separate clientside application programs from complicated primary business services, then client application program can be developed more easily. By use of ASP components based on COM+, parts of ASP script program can be encapsulated into ASP components, accordingly large script programs can be reused and system can be more safety (Sbelleys 2001). Primary business components are kernel of business logic layer, a few business components are designed here. Data access components provide services for primary business components, and it includes data validity check, data records' append, modification, and delete, etc.

The system layer framework can not only be divided into three-tiers: presentation, business logic and data, but also be partition into five-tiers: user interface, facade layer, primary business layer, data access layer, and data layer, and layers rely on each other.

![Diagram](image)

**Fig.3.** Reconfigurable shop floor control system architecture

5 COMPONENTS AND XML APPLICATION

5.1 Reconfigurable components design

System components design should follow the rule that the system designed be flexible, scalable, and reusable. Components we designed adopt COM+ standard. COM+ standard provides component interface standard and mutual operate mechanism. Components include use case, analysis, design, and model realize elements, and involve interface descriptions, subsystem, and attribute type. All the types, classes, interfaces, attributes, objects, and subsystems should be packed and related files should be set up. We use UML models to decompose IDEF models into reusable components with adapt size and structure (Shang 2004a).

According to system design and develop, we can sum up system components size partition rules as follows:

1. Design reuse should be more important than code reuse. Design reuse should be guaranteed as code reuse being analyzed. Components can be designed with Design patterns, such as ECC (Engine Collection-Class, etc).

2. User individual requirements should be realized on business logic layer. For example, searches a data table according to different conditions. System component can be realized on business logic layer, it can transfer data layer by special demands, and operate data, then send the result back to presentation layer.

3. For web applications, data present should be separated from data operate. XML technique can answer for the requirement. Data input by user can be structured into XML format, then the system can interpret and complete related logic operation. A set of interfaces to search data are offered, then operated XML data fetched from the data base can be displayed on HTML page layout through interfaces.

4. Component partition should be based on the system layer design for three-tier or five-tier layer architecture. Component can be partition discretionarily according as developers’ practice or different applications, while system layer design shows the system logic structure.

5. Component size. Component is class container. Classes with similar functions can be encapsulated into a component. Commonly, a component should not be very large. A component is used to realize a kind of similar application request, not include various functions.

6. Component status. Component is objects encapsulated. The components’ usability lay on the encapsulated objects’ usability. Objects without state are more reusable than objects with state, and generally, objects without state are used on data layer.

7. Rule of “strong aggregation inner, loose coupling”. Objects inside a component are generally strong aggregated, and components are loose coupling with each other. Strong aggregation requires that a component completes an exclusive task approvingly, loose coupling decide the mutually transfer relationship between components.

Be living in the development process, in macroscopic step, component-oriented idea is carried on system modeling and system architecture analysis, system run efficiency analysis, stability analysis, and maintenance efficiency analysis. In microcosmic step, object-oriented idea is carried on system modules partition and affair analysis. Arithmetic realiza-
tion is carried out in the way of procedure-oriented idea.

5.2 XML application

"Browser+ web server+ data server" is adopted in traditional web information integration, the architectural structure has shortage as follows: information mutual capability is bad, web pages need to be constantly refurbished, system is inefficient, affair transaction weakly, development and program is not agile, and cannot be integrated with the old information system commendably (Somjit & Dentcho 2003).

Web information integration based on XML combine web technique with traditional client server, which makes up the shortage of web information integration based on HTML. XML standard can meet loose coupling and scalability of system. XML is used to describe all kinds of datum and provides data exchange between different environments, separate data display from data operate, enhance data reusability.

XML applications in reconfigurable shop floor control system:
(1) Scalable three-tiers model based on XML. We develop scalable three-tiers architecture, namely five-tiers: user interface layer, facade layer, primary business layer, data access layer, and data layer. Datum in user interface layer, facade layer, primary business layer, data access layer are XML format. Data layer send users' requests for data to data-base, and pass back results to user with XML format string, at the same time transfer users' update results in XML format for data-base into data-base command, then submit to data-base.

(2) Information exchange and integration based on XML. XML format documents are main mode of data denote in all the layers, and information is exchanged in different layers with XML string.

(3) Information share based on XML. Data content is separated from data display, data reuse is enhanced, and data between different systems is shared with XML format. Data access layer based on XML conform different data resources, which makes for information resources share.

By XML application, web pages need not to be constantly refurbished, information mutual capability is enhanced largely, system network efficiency and data flux tend to be in reason, data in server-side can be exchanged to client-side efficiently and be processed by all kinds of scripts and components. Different level application platforms of system are utilized availably, and system efficiency is improved (Petrou & Martakos 1999).

6 CONCLUSION

A reconfigurable shop floor control system has been developed, which is realized on the environment of Windows2000, IIS 5.0, Oracle 8.05, VC6.0. The system designed has been used to control two different types of shop floors in a machine tool company, which is configurable, scalable and reusable. During system development and application, only user interface layer, business logic layer and data access layer need to be fewer modified to adapt changed consumer requirements, which ensures system to be lusty, scalable, and reconfigurable.

On the research of reconfigurable shop floor control system, we studied system modeling (Shang 2004a), shop floor model framework (Shang 2004b), component design (Shang 2004a), system function reconfigure based on knowledge (Pan et al 2004, Zhang et al, 2003 ). Theories and approaches about domain reconfiguration analysis, component dynamic configure, and system function configure are our future work directions.

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