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Cloud Service-Oriented Dashboard for Work Cell Management in RFID-enabled Ubiquitous Manufacturing

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***Abstract*—This article aims at developing a service-oriented dashboard for operators and supervisors of manufacturing shopfloor work-cells to realize information visibility and traceability effectively with cloud and RFID (radio frequency identification) technologies. The work is based on a case of an illustrative assembly line consisting of a number of work cells. The dashboard is deployed for facilitating assembly operations in ubiquitous manufacturing environment. The utilization of the system leads to significant improvements in work cell productivity and quality, operational flexibility and decision efficiency.**

***Keywords*—Service-Oriented Architecture (SOA), Ubiquitous Manufacturing, Cloud computing, Work Cell, Management Dashboard, RFID**

I. INTRODUCTION

Manufacturing enterprises manage their infrastructure according to normal manufacturing hierarchy which consists of three levels, enterprise level, shop floor level and work cell level [1]. A manufacturing factory hosts one or more shop floors, each of which consists of several work cells. As part of a large manufacturing shop floor, a work cell involves various manufacturing objects, such as operators, machines, materials, work sheets etc. [2]. In addition, a work cell is not simply a layout, in which dedicated equipment and materials to a family of parts or products with similar processing needs are closely connected with work tasks and those who perform them in terms of time, space and information [3]. The management of the work cell is a vital part of shop floor management and directly related to operator productivity, machine utilization and maintenance, product quality, work-in-process (WIP) inventory etc. Inefficient and ineffective work cell management could cause “butterfly effects” to an enterprise such as reduction of shop floor productivity and quality, increasing of manufacturing lead-time and customer dissatisfaction.

An enormous amount of research studies on manufacturing work cells have mainly concentrated on developing mathematical (or simulation) solutions for work cells-related technical problems, such as cell formulation, job design, production planning, part routings, machine requirements, material handling equipment and so on. [4]. A wide variety of metaheuristics and computational algorithms have been proposed with the aims of minimizing inter-cell movements, improving part routing flexibility, reducing work-in-process inventory etc. [5-7]. However, busy work cells are far more dynamic and complex currently due to the varieties in production requirements, the adoptions of advanced and sophisticated manufacturing technologies and stochastic disturbances like machine breakdowns. Optimal design of work cells alone, as discussed in the literature, is insufficient to ensure and achieve the optimal performance of work cells in terms of effectiveness and efficiency. Although improvements of manufacturing shop floor management have been paid great attention on, paucity of literature is concentrated on enhancing work cell management [8, 9].

A work cell is a basic unit of the value-adding manufacturing systems. Because of the fast and steady growth of product variety, it is necessary for manufacturing enterprises to improve work cell productivity and quality. This study concerns with shop floor management and focuses on work cell management. In work cell management, accessibility to real-time information about dynamic work cell situations appears to be essential. Furthermore, it is challengeable for these enterprises to make accurate work cell decisions and execute appropriate production operations without real-time information on hand. Therefore, precise work-cell information should be provided to work-cell operators and shop-floor managers on real-time base for making well-informed decisions.

In ubiquitous manufacturing environment facilitated with Radio Frequency Identification (RFID) technology, several challenges are open for investigation to improve work-cell productivity and quality. The first challenge is to determine which kinds of real-time information should be provided to reflect the dynamic environments of work cells. The second challenge is how these kinds of highly related information could be offered and updated to associated operators visually for adaptive decision making. The third challenge is how to flexibly deliver the required information in a cost-effective way with existing information technologies.

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To deal with above challenges, this paper proposes a service-oriented dashboard for manufacturers to realize information visibility and traceability effectively and to facilitate adaptive decision making within the already well-formed work cells. Moreover, the proposed system is demonstrated by an assembly work cell case where a dashboard is deployed for facilitating assembly operations in ubiquitous manufacturing environment. The utilization of the system leads to significant improvement in work cell productivity and quality, operational flexibility and decision efficiency.

The rest of the paper is organized as follows. Section 2 presents the overall architecture of the proposed dashboard system. Key cutting-edge technologies utilized to design and develop the dashboard system are described in section 3. Section 4 reports a case study on the implementation of the dashboard system for a typical assembly work cell. Conclusions and future works are given in section 5.

II. OVERALL ARCHITECTURE OF DASHBOARD

The concept of dashboard comes from a management assistance program of SAP called Management Cockpit. The Management Cockpit displays important data in sequence on the meeting room walls to support strategic decisions [10]. Various cockpits have been adopted to manage business process, monitor and control software development project and collaborate Automation System Engineering projects [11-14]. This study proposed the design concept of work cell management dashboard which will collect and integrate data from heterogeneous data sources, visualize meaningful real-time information, as well as support decision making of shop floor managers and work cell operators. With the proposed dashboard, right information content can be provided in the right format to the right person in right time.

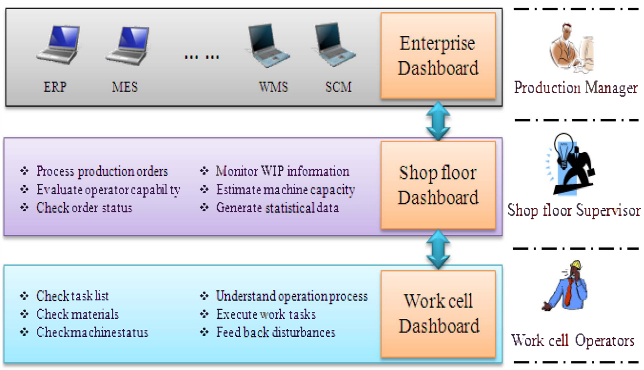

Figure 1. Overview of dashboard architecture

Fig. 1 shows an overview of the dashboard system. Right-hand side of the figure lists representative users at three different levels. There are three key components in the dashboard system, namely, Enterprise Dashboard, Shop floor Dashboard and Work cell Dashboard. Enterprise Dashboard is integrated with existing information systems like ERP, MES and WMS. Shop floor Dashboard is responsible for displaying information about the status and progress of each work task executed in distributed work cells and supporting planning and controlling decisions. Work cell Dashboards are responsible for displaying timely information about machines, materials, work sheets etc. as well as assisting work cell planning, execution and control. In RFID-enabled ubiquitous manufacturing environment, smart object and gateway enabled real-time information capturing and processing forms a solid foundation for dashboard system [1, 2]. This paper focuses on Shop floor Dashboard and Work cell Dashboard that will be detailed one by one in the following sections.

A. *Real-time Supervision with Shop floor Dashboard*

Shop floor dashboard facilities are characteristically implemented as web applications, and remotely accessed through shop floor gateways. The left-hand side of Fig. 1 shows several representative functions. The main users are shop floor supervisors who receive production plans from the enterprise dashboard. Subsequently, production plans are divided into work tasks which will be scheduled to distributed work cells according to real-time work cell situations, operator capability, machine capacity, delivery data etc. Shop floor supervisors may re-assign work tasks dynamically due to random disturbances like machine breakdown. Order status and WIP information are always monitored in case of order delay and high WIP inventory. Finally, a wide variety of in-depth statistical analyses are carried out to measure the performances and progresses and reveal underlying process bottleneck problems promptly.

B. *Real-time Operation with Work cell Dashboard*

Work cell dashboard facilities are characteristically implemented as mobile applications and accessed through handheld or mobile devices. Work cell operators are the main users. A typical work cell operation cycle, which is showed on the left-hand side of Fig. 1, consists of five steps. The process begins with the operator checking his task list. Before execution, the operator needs to check required materials and machines. Moreover, a work sheet about the operation process will be offered to instruct the production operation. Finally, the operator executes work tasks according to respective work sheets. All disturbances should be timely fed back to Shop floor Dashboard through Work cell Dashboard whenever and wherever they happen.

III. CONSIDERATIONS FOR DESIGNING, IMPLEMENTING AND DEPLOYING DASHBOARD

The adoption of suitable information technologies plays a critical role for displaying different information content in different forms to different users flexibly and economically. As shown in Fig. 2, two components are of significant importance for designing, implementing and deploying the proposed dashboard system, namely dashboard information service, service oriented architecture.

A. *Dashboard Information Service*

Dashboard Information Service is shown on the left-hand side in the middle of Fig. 2. The objective of the dashboard information service is to build up a bridge for information communication between the dashboard applications and heterogeneous information source shown on the bottom of Fig. 2. Information source can be divided into three categories. The first category consists of third-party native enterprise information systems (EISs) such as ERP, WMS, MES and PDM systems. The second category contains data sources directly from different types of native database systems. The third category includes standard web services which can be deployed by Cloud computing to reduce start-up investment costs of the proposed dashboard system.

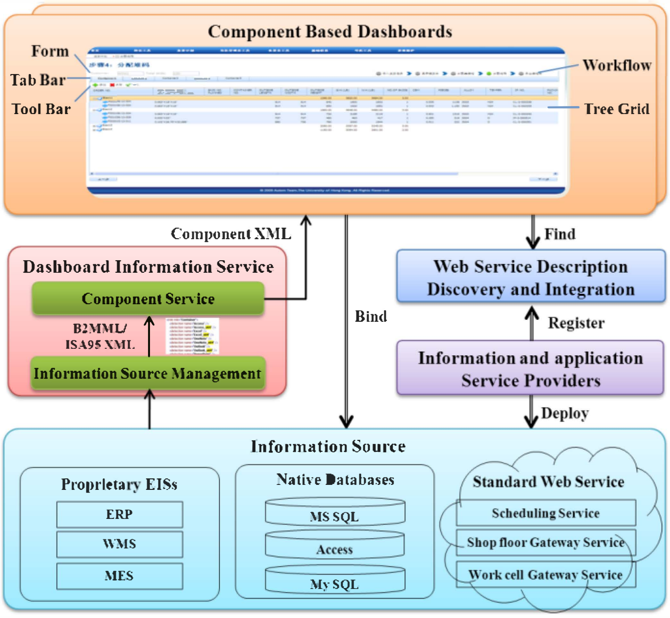

Figure 2. Key technologies adopted in the dashboard system

Dashboard Information Service provides two levels of information management services. One level is Information Source Management which manages the information between information source and XML-based information models following some domain standards (e.g. B2MML-data standards for business to manufacturing integration). The other level is Component Service which realizes dual-way conversion of XML document between domain data standards (e.g. B2MML) and component standards (e.g. DHTMLX).

B. *Service-Oriented Architecture*

The dashboard system is developed and operated following a standard service-oriented architecture (SOA). A complete SOA process involves four main phases: Register/Publish, Deploy, Find and Bind as shown on the right-hand side in the middle of Fig. 2. Service developers/providers deploy their web services at the assigned web sites (e.g. Cloud computing) and publish the details of these services including location, capacity as well as interfacial description. Service consumers search and select proper web services from the published database and invoke them during a specific application process.

Three fundamental web service tools are involved in these four typical phases. They are universal description, discovery and integration (UDDI), web services description language (WSDL) and simple object access protocol (SOAP). UDDI is a platform-independent, XML-based registry for distributed services to list themselves on the internet. WSDL standard provides a uniform way of describing the abstract interface and protocol bindings of these services. In other words, a WSDL describes what a web service can do, where it resides, and how to invoke it. SOAP is a platform-independent protocol for invoking those distributed web services through exchanging XML-based messages.

IV. CASE STUDY

A. *Case Description and Working Procedure*

This section demonstrates the usage of the proposed dashboard system with an example application of a walking-worker fixed-position assembly shop floor where products are placed at work cells. Workers move from one work cell to another to complete assembly tasks. The product demonstrated consists of five modules which are assembled sequentially across three assembly processes. At the first process, two modules, one of which is a critical component, are put together to form the first level subassembly. Two other modules are added to the subassembly at the second process. The last module is assembled to produce the finished product at the third process. On this shop floor, three assembly operators are involved in three assembly processes respectively, and each of them is equipped with a handheld work cell dashboard.

B. *Real-time Visibility with work cell Dashboard*

The assembly processes of three assemble operators are rationalized. For simplicity but without commonality, one assembly process will be used to demonstrate how the work cell dashboard facilitates work cell management. One working cycle includes four steps.

1) Check assembly tasks: Firstly, the assembly operator checks and chooses his assembly tasks with his handheld dashboard, as seen in Fig. 3 (a). Then he/she goes to corresponding work cell to execute work tasks.

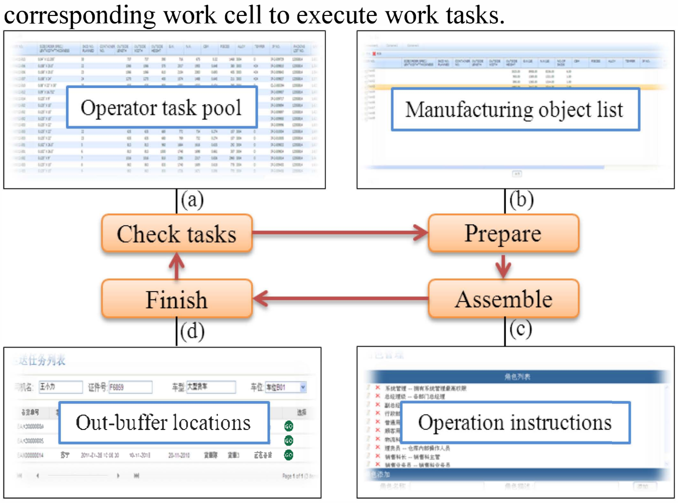

Figure 3. Real-time visibility with work cell dashboard

2) Prepare: Before assembly, the operator needs to check all the required items and equipment required by the *applications provided by the work cell dashboard as shown in Fig. 3 (b).*

3) Assemble: If all required items and equipment are checked successfully, a detailed assembly process prompts to illustrate the assembly process, as seen in Fig. 3 (c). The operator needs to execute assembly tasks according to respective instructions.

4) Put finished products into out-buffer: After each finished product is produced, the dashboard system will prompt the operator to put it to the out-buffer of this work cell as shown in Fig. 3 (d). Then the operator checks and chooses his assembly tasks again until all tasks are finished.

The use of the proposed system will significantly improve the performance of work cell planning, execution and control which directly leads to improvement in operator productivity, machine utilization and maintenance, product quality, WIP inventory and etc. In consequence of excellent work cell performance, shop floor productivity and quality can be enhanced. At last, manufacturing enterprises can keep their competitive edge in dynamic business environment.

V. CONCLUSIONS

The service-oriented dashboard is a work cell management system which is based on RFID-enabled real-time visibility and traceability. On one hand, the information displayed on the dashboard is always consistent with work-cell real-life conditions. Therefore, work-cell operators and shop-floor managers can make accurate operational and strategic decisions. On the other hand, the ending condition of one operation is the beginning condition of another operation. All discrete operational events are closely connected in terms of time, space and information to realize good traceability.

Three contributions are important in this research and development effort. The first contribution is the innovative dashboard technology for work-cell operation management. It is necessary to make accurate work-cell decisions with updated information for meeting dramatically changing customers' requirements. The second contribution is the use of SOA, XML-based schema and Cloud computing technology. These core technologies ensure the adoption feasibility of the dashboard management system by small and medium-sized enterprises. The third contribution is the proposed assembly work cell case which forms good-practice guidelines for deployment of this service-oriented work cell management solution. Practitioners can implement the most suitable system with appropriate information content and display form according to their own demands.

In shop floor management, internal logistics operation management is equally important to work cell management. The current work will be extended with logistics dashboard system in our future research.

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