Applying RFID for Synchronization of Factory Floor Documentation in Robotic Manufacturing Cells

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Abstract. The goal of this article is to present the conceptual model of RFID technology integration with manufacturing information and control system. Offered ideas are motivated to achieve seamless connection between automatic identification of parts on the shop floor level and CAD/CAM/MES and ERP system. The mentioned connection could be accomplished by use of RFID technology to transfer data from shop floor level into MES environment. Modern CAD/CAM systems such as NX provide wide possibilities for generating electronic reports, such as operation lists, setup instruction, tool report, according to own customization. Therefore, the process of shop floor documentation creation in html format is described in this paper as well.

Introduction

RFID is presently dramatically expanding technology that penetrated into different areas such as supply chain management, manufacturing, departments of defense and other important fields to ensure contactless identification and tracking of goods, property, but also people in real time. From the literature sources [1, 2, 3] there are also well known RFID solutions in an area of factory automation with aim to gather data from a shop floor layer to higher layers, especially to manufacturing execution systems (MES). An equally important task in building factory automation is a problem of on-line requisition of floor shop documentation based on occurring changes in batches. For this purpose, potential of RFID technology incorporated into a manufacturing execution system can be exploited. The main scope of the article is to outline how to identify changes in batches for synchronization of shop floor documentation by using NX CAM for manufacturing. Modular NX system provides wide possibilities for generating electronic reports, such as operation lists, setup instruction, tool report, according to own customization. Therefore, in this paper process of shop floor documentation creation in html format is also described.

Related Work

The call for effective on-line control techniques for manufacturing systems is becoming more acute because of increasing competitive pressures. This need is particularly aimed at flexible manufacturing systems (FMSs), where several part types with short lead times are produced using multiple resources with limited capacities. These resources include the personnel, machines, robots material handling systems, and auxiliary resources (e.g., pallets, fixtures, and tools) [4]. The framework of a general method for on-line control in a job shop environment with multi-resource requirements and setup times through Petri net model has been presented by Artigeus and Roubellat [5]. Since the Petri nets are based on a precise characterization of significant states, decisions and events, this method suggests the appropriate scheduling decisions in real time based on occurring events and updates the set of solutions accordingly.

As it was outlined above MES applications have significant potential to support real-time production control as well as data collection and reporting. The common characteristic of MES is
that it bridges gaps between ERP system and shop floor controllers by supporting various execution activities in real time [6]. The seamless communication with shop floor personnel can be accomplished by use of on-line connection and web-based documentation. One of the ways how to facilitate shop floor documentation is use of product data management (PDM) software, which provides integrated environment for tracking and updating product information [7]. However, the implementation of PDM into existing factory could make demands on increasing costs. Therefore, there is another way to solve problem of improvement of information flow, and that is in utilization of the existing CAD/CAM software. Manufacturing companies that use for drawing 3D part modeling and programming the NC programs software like Pro/Engineer by PTC or NX (Siemens PLM) can use their extended modules to create web-based shop floor documentation.

It is generally indicated that RFID technology creates important part of manufacturing process automation in on-line communication. RFID applications are normally closely tied to the MES controlling production process. The typical functionalities of MES are described by several authors [8], [9]. Radio frequency identification technology may support most of these functionalities. In operations scheduling and production control, RFID can be used for guaranteeing process safety and interlocking. If materials or material containers are equipped with a unique ID, the MES can ensure that all preceding process steps have been conducted successfully before starting the next manufacturing step. Furthermore, production order data and manufacturing parameters can be written to the RFID tag at the first manufacturing step and then they can be read and updated [10]. Some aspects about implementation of RFID in smart manufacturing related to self-identification, communication, quality, and concurrent process have been revealed in [11].

Another well-known solution related to our research is based on the demand of cutting tool that is on-line triggered from the shop floor layer [12]. Each CNC tool is attached with a RFID tag that records tool preset data, operation data and usage time. After the completion of each operation, the RFID encoder writes the usage time of the tool onto RFID tag and updates the system. Panjaitan and Frey [13] presented in their work a solution of on-line product driven-control in manufacturing systems equipped with RFID technology using functionality based control. The mentioned approach gives capability to the products to decide their own control strategy by means of task schedules in a system process which paves a way to develop intelligent products. An example of drill station with some cases of arrivals and kinds of products has been given in their work.

Creation of factory floor documentation in NX CAM environment

NX is complex CAD/CAM/CAE software that supports wide range of activities in design, manufacturing and engineering. It also represents a modular system, which means that each workstation can be configured as required, with full associative to all cooperating modules. This allows simultaneous work for the team of investigators, what in effect means that in some stage of semi-finished model can be performed simultaneously strength and kinematic calculations or further analysis and simulations. In addition, the individual modules can be shared over a local network (so-called floating license) and configured as necessary.

NX CAM program provides practically unlimited possibilities in a process of determination of technological operations. Technologist disposes besides the whole line of fully automated machining processes also a multifunction apparatus for generating user specifically requested types of machining and special technologies. Generated cutting tool paths are fully associative with the model and any accepted changes made in the model lead to a cutting tool path change.

We can use the model that is created by combining bulk solids, surface or curves, but also imported model from the other CAD systems to generate NC program. The system provides output of NC program to a machine of all major manufacturers, and also allows to suit of special demands by post-processor generator. NX also supports advanced high-speed machining and the automatic
creation of shop floor documentation in HTML the content of which consists of methods, operations, cutting sequences, cutting tool list and others.

Module of Shop Documentation generates web-based shop floor documentation according to template that has to be programmed. The template programming uses a script language called TCL (Tool Command Language) with the extended library of the command for NX. HTML can be used to create interactive forms with structured document and embedded images. CSS (Cascading Style Sheets) is markup language, which define the appearance and layout of text and other object. Fig. 1a shows HTML and CSS code embedded in the template source document.

![Fig. 1 Fragment of a) HTML and CSS source code; and b) HTML embedded in the template file with Tcl source code](image1.png)

Fig. 1b shows the structure of the code for template programming. TCL code is denoted in the template file with opening and closing square brackets. There is provided the practical example using the MOM_cycle_objects command which cycles all parameters and attributes for each object. Output represents the formatted information in HTML code according to command string. For this specific case the command, from extended library of the NX commands, searches for all operations within the part. The output of the given source code is formatted data in HTML page. The benefit of such documentation is the achievement of simplification in organization and presentation data for information retrieval, and also it is the guarantee of information updates. The contribution of web-based documentation is also online communication between the layers within company. This allows also revealing an occurrence of errors before production starting.

![Fig. 2 Output of template for NX web-based shop floor documentation: a) index page; and b) cutting sequence](image2.png)

The full version of html-based documentation is shown in Fig. 2. The basic idea of improvement is in substitution of all reports and manuals for web-based shop floor documentation. This includes the image of 3D part model, the information of used materials, a setup instruction, tool report
including individual tool information and image, customizable NC steps information such as cutting condition, machining time, etc. Fig. 2b shows subpage that captures operation sequence information with the tool path graphics for each NC step.

Module Shop floor documentation can be also used in connection with SQL database. The bridge between the module and SQL database is provided by TCL-SQL library that enables transfer of information by use of extended commands. That’s why the outputs such as files of NC programs, cutting tool lists, methods, technological operations, snapshots of virtual 3D part model, etc., can be inserted and stored in the SQL database located and managed at the database server. It is very efficient to assign unique ID code to constituent data stored in the SQL database.

**Synchronization of factory floor documentation with production demands**

**Description of RFID-Based Trace and Tracking System to Synchronizes Documentation.** The evolution of RFID technology in production opens doors to new opportunities of automation also to enhance the on-line control technique. The proposed model describes a possible application of RFID technology in cooperation with MES system, and also the use of NX software that provides a web-based documentation. Conceptual model of on-line synchronization of web-based documentation using RFID technology (as shown in Fig. 3a) consists of following components:

- **Server** allows or denies received ID code of workpiece with embedded RFID from middleware to assign an actual NC program selected from SQL database. First, the application layer checks whether the CNC machine is busy or idle. Then it triggers the GNCP (Get NC program) procedure that detects if the selected NC program file is already loaded in Robotic machine tool control system (see Fig. 3b). If selected NC program file from SQL database does not match to loaded NC program file in control system then the application server sends the selected NC program file to Robotic machine tool.

- **Middleware** presents a platform that manages and routes data between tag readers or other automatic identification devices and enterprise systems. In our case it selects and transforms data from the RFID reader to Application software.

- **Computer PCNX** contains installed NX software along with a predefined template for submission NC programs to the SQL database.

**Fig. 3 Scheme of seamless integration of RFID technology with NX system (a) with Algorithm of GNCP procedure (b)**

Summarily, functions of the conceptual model are as follows: Designer uses NX software on PCNX for the drawing objects in 3D views and assigns needed tools, operations and methods of machining to a file of part in the CAM environment of CAD/CAM system. Subsequently, a type of NC machine tool from a predefined library of machines is chosen. Then designer starts module...
Shop floor documentation for creation of NC program for PLC and other digital outputs that are sent to SQL database.

RFID Reader transforms the input signal from antenna to a Middleware data that is understandable for software application. The workpiece is located on conveyor that serves also as input/output station for the robotic manufacturing cell. The type of workpiece with embedded RFID tag is identified before it is moved into input station position of the robotic manufacturing cell. Middleware receives data from the RFID reader and subsequently after their processing they are passed to the application software. NC program after its selecting from SQL database is transferred to the Controller of Robotic machine tool and the web-based shop floor documentation on a PC terminal is synchronized with identified workpiece at the same time.

**Releasing Orders Based on Production Demands.** Typical robotic manufacturing cell processing high variety parts grouped into families according to manufacturing orders. It is very crucial to determine the sequence of orders with objective of minimization of total cycle time. This problem is proven to be strongly NP-hard, but a lot of effective approximation algorithms have been developed for obtaining near-optimal solutions. Such solutions intensify efficiency of the robotic manufacturing cells. Based on the existing literature on manufacturing scheduling, there is variety of strategy that is applied in sequencing. Considering the existing trend in reducing manufacturing lead times, the most frequent optimality criterion for this purpose is makespan that is defined as maximal completion time of all processing orders [14]. The fundamentally categories of algorithms for this criterion are exact and approximate methods. Naturally, it makes sense to deal with progressive sequencing method like GA-based hybrid algorithms. In proposed integrated system we apply GA-based algorithm [15] to find and optimal permutation of jobs.

In order to illustrate a use of the optimization tool described above in combination with other elements of the conceptual model, the following assumption can be made. For example, three-machine flow shop is connected with single robot that may be used as a stock. The transfer time is constant value T. Basically we can model this system as a F3/no-wait/Cmax problem. The whole model is represented in Fig. 4a, where we can see the processing times for three jobs that need to be scheduled. For this we can apply GA-based algorithm to find an optimal order of jobs to satisfy the optimality criterion that is defined as maximal completion time of all processing jobs. For a given case the optimal sequence of jobs is J2-J1-J3. Graphical representation of the solution to this simplified problem is depicted in Fig. 4b.

![Jobs-Machines](image1)

**Fig. 4 Simple example of the flow-shop problem:** a) Instance matrix; and b) Makespan determination using Gantt chart technique

**Conclusion**

In spite of mentioned advantages of RFID technology, there are still skeptic views on its exploitation due to certain limits and disadvantages that have not been the issue of this article. On the other hand RFID offers uncovered potential of practical applications for efficiency increase in production and material handling. Described concept with use of RFID technology in manufacturing processes linked with CAD/CAM system that uses NX system should contribute to increase a level of automation in specified functions after its verifying. Moreover, presented solution creates conditions for full automation of machine toll workstations without human operators. The target of
a subsequent research, before its implementation to the real manufacturing process, is to investigate the feasibility of model for HW/SW tools specification.

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References


