Implementation of Reconfigurable Manufacturing System using I-plant

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Key words: Planning Table, Reconfigurable Manufacturing System, Modular System, Digital Factory

1. Introduction

In nowadays market situation, enterprises have to face challenges of globalization, rapidly changing demands and continuous improvements of technologies for manufacturing activities. The main duty of enterprises to ensure their survival is reducing the time to introduce new products with high quality and low cost to the market. A manufacturing system is, therefore, required to have the characteristics of short design cycle, short ramp-up, low reconfigure cost, good production quality together with the benefits of mass production.

Reconfigurable manufacturing systems (RMSs) arise as a solution for the problem. An RMS, which is customizable, convertible and scalable, allows current production structure to be transformed with low cost and no significant loss in productivity and quality. This transformation is performed more and more frequently to response to dynamic requirements of customers. Hence, the planning of such systems must be considered as a continuous process and new tools and methods are needed to support new planning paradigm.

This paper proposes an architecture in which modular concept and rule-based reconfiguring algorithm are combined and applied into a factory planning tool, I-plant in this case, to enable RMSs designing. Modular concept provides the designed system with modularity and integrability. That means the system is built up from various modules, self-contained components performing a specific task, and these modules can easily be added, removed or replaced to meet new requirements. Each module is attached with a set of rules defining its reaction toward probable changes of products. Then, reconfiguring tasks can be obtained by an inference engine based on those rules.

2. Modular concept in system planning

According to Koren Y. [1], ideal RMSs possess six core characteristics: Modularity, Integrability, Customization, Scalability, Convertibility and Diagnosability. Modularity, Integrability and Diagnosability reduce reconfiguration time and effort; Customization and Convertibility reduce cost. A typical RMS can have several of these characteristics, though not necessary all. However, to achieve any of these characteristics, an RMS must be developed with modular thinking in mind.

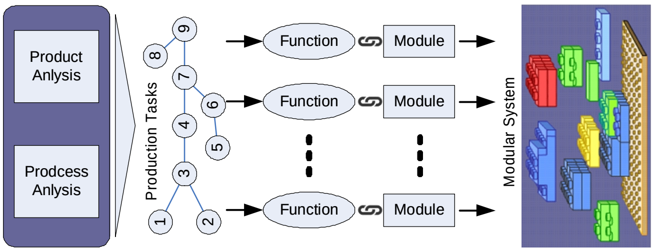

Fig. 1. System planning with modular concept

From the analysis of products and production conditions, all functions needed for manufacturing process are grasped. Each function will carry out a specific task of the system and is, then, assigned to a component or a group of components. These components, or groups of components, are considered as modules which are linked together to form a full-fledged manufacturing system (Fig. 1). The system is now a combination of modules arranged in a hierarchical structure. Transformations of the system can be performed by modifying this structure, which means modules can be added, removed or replaced to reform the system, according to the requirements.

3. Rule-based reconfiguration

The modular concept provides a production system with the ability to be transformed in structure, scale, capacity to meet new requirements. Instead of starting from scratch, designers can quickly reconfigure the existing system by altering some modules based on the analysis of how changes will affect the system.

There are many factors whose changes will influence the structure of a manufacturing system. These factors are considered as change drives. Several change drives can be figured out during the analysis of products and production conditions. Some of common change drives are product geometry (dimension, shape, surface form…), the ratio between processing time and cycle time which varies in different products and technologies to perform a specific task.

To determine how the structure of a system is affected when changes occur, the relations between changes drives and the functionalities of modules are analyzed. Based on the analysis, a set of rules is assigned to each modules in the library indicating its behaviors against different change drives. With that knowledge base, a software can automatically generate a list of tasks needed to perform when the system is reconfigured in reaction to change drives.

4. Interactive system design with planning table

In order to quickly response to the changing demands, production systems have to be changed and optimized frequently according to needs of the current production program, current requirements of customers and current abilities of suppliers. Hence, the planning of a production system must be understood as a continuous process. Therefore, a new paradigm is required for the planning of RMSs in which the one-off character of planning is replaced by continuity.

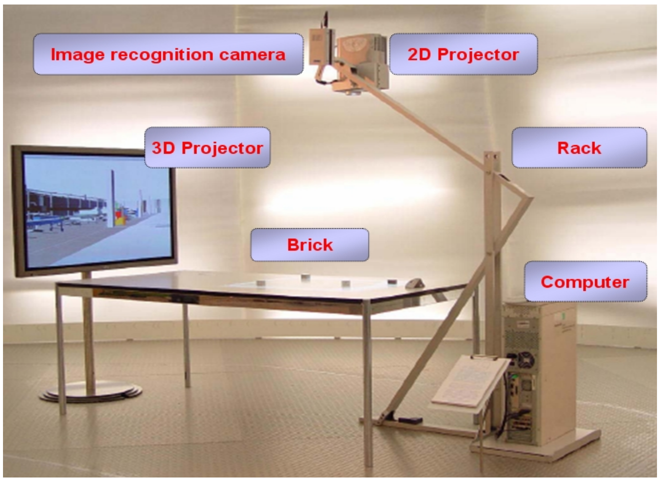

Fig. 2. Planning table

To enable this paradigm, a system called "planning round table" has been developed at the Fraunhofer Institute for Manufacturing and Automation (IPA) in cooperation with the University of Stuttgart. The system enables direct interaction of a working team with computers through an images recognition solution composed of hardware and software. A 2D image of planning area is projected onto a table which the team is working on. Object picking is done through small bricks with a reflection device which is recognized by a camera scanning the working area on the table. A 3D visualization of the layout is projected onto the wall. The software, called I-plant, is the core of the system, responsible for combining operations of all the hardware to perform planning tasks.

Due to the integration of all workers in planning activities, the planning table offers a significant reduction of planning time and an increased planning quality.

5. Implementation of rule-based reconfiguration

To reduce time and human word, the reconfiguration process should be automated by using software. In this paper, an application is programmed to provide an easy-to-use tool for the design work. The overall architecture of the application is shown on Fig. 3. As displayed on the figure, at the first stage, the software receives change drives derived from the product and production conditions analysis as input parameters. Then, it will load existing rules which are related to the input change drives from a pre-built knowledgebase. These rules and all information of change drives are, then, sent to an inference engine. The inference engine will evaluate these rules to determine which modules in the project database should be added, removed, replaced or modified. In case a module needs to be replaced, the engine will select the most appropriate module from the module library. If the required module is not available in the module library, the software will suggest developing a new module after providing some specifications and requirements of the new module. In another case, if a module needs to be modified, the software will open the model in a 3D CAD tool such as CATIA and give designers some instructions to modify the module.

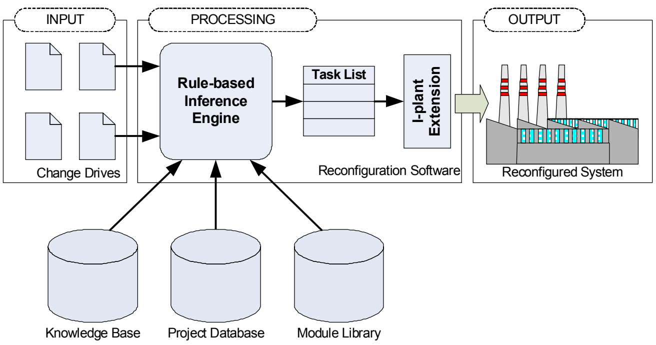

Fig. 3. Software architecture

All required actions are then gathered in to a task list. To deal with this task list, another program was developed as an extension of I-plant. The extension provides the designers with an interactive GUI interface to manipulate the reconfiguration tasks. The designers just have to decide which action will be applied and do some modification as fine tuning. After all those steps, a new design of production system is obtained. Most of the complicated works are solved by the computer, therefore, it speed up the reconfiguration time while remaining the quality of the design.

6. Conclusions

In order to be highly competitive in the turbulent global market, enterprise have to shorten the interval of introducing new products and diversify their products. As a result of this trend, manufacturing systems are forced to be changed more and more frequently to adapt to new products, new technologies. This paper presented a strategy to design a reconfigurable manufacturing system which is capable of being transformed quickly in reaction to satisfy the different requirements of products in the same family.

The main idea of this paper is based on the modular concept of RMSs. As an RMS is constructed from a hierarchical structure of modules, the relations between the functionalities of these modules and the required functions according to change drives can be analyzed. With the result of the analysis, a knowledgebase consists of many rules indicating each module's behaviors is built. These rules are, then, implemented by programming and integrated into a factory design application called I-plant. With the help of software, the redesign time and cost can be significantly reduced.

Due to the generalized property of the strategy, it can be applied into different manufacturing systems of different kinds of products. Also, not only I-plant but also other planning program can utilize the approach to support the design of RMSs.

REFERENCES

1. Koren, Y., Jovane, F., Heisel, U., Moriwaki,, T., Pritschow G., Ulsoy G., and VanBrussel H., "Reconfigurable Manufacturing Systems. A Keynote paper", CIRP Annals, Vol. 48, No. 2, pp. 6-12, November 1999.
2. Mehrabi, M.G., Ulsoy, A.G., and Koren Y., "Reconfiguring Manufacturing Systems and Their Enabling Technologies".
3. Mehrabi, M.G., Ulsoy, A.G., and Koren Y., "Reconfigurable Manufacturing Systems: Key to Future Manufacturing".
4. Park, H.S., Do, D.A., and Lee, G.B., "Development of a Modular Manufacturing System with High Adaptability".
5. Westkaemper, E., Sihn, W., and von Briel, R., "Interactive Factory Planning", Proceedings of the LASTED International Conference Software Engineering and Application (SEA'99), October 6-8, 1999, Scottsdale, Arizona, USA.
6. Sihn, W., Bischoff, J., von Briel, R. And Josten, M., "Planning around the Table: A New Approach towards a Continuous Factory Planning Process", The 33^{rd} CIRP International Seminar on Manufacturing Systems, 5-7 June 2000, Stockholm, Sweden.
7. Sith, W., Bischoff, J., and von Briel, R., "Integrated modelling and visualization of production systems".
8. Galan, R., Racero, J., Eguia, I., and Garcia, J.M., "A systematic approach for product families formation in Reconfigurable Manufacturing Systems", Robotics and Computer-Integrated Manufacturing 23 (2007) 489-502.
9. Zamfirescu, C., Valckenaers, P., van Brussel, H.H., and Germain, B.S., "A Case Study for Modular Plant Control", HoloMAS 2003, LNAI 2744, pp. 268-279, 2003.
10. Wang, F., Xu, D., Tan, M., and Wan, Z., "A Holonic Architecture for Reconfigurable Manufacturing Systems".