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An All Lifetime Upgradable Open CNC System Structure and its Implementation

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Abstract: CNC system plays as the brain of Machine tools. Due to customized manufacturing, many special NC functions are required for special machine tools. Open CNC systems for customized manufacturing are urgently needed. But according to the other research results of open CNC system, complex code programming and debugging are still needed. In this study, an all lifetime upgradable open CNC system structure and implementing method are developed and also a case study is given as well. With this structure, the software of NC system is divided into function related design process and function non-related design process. For software, the function related design process can be realized by graphical modelling in order to ease the heavy design and debug burden. For hardware, fieldbus technology is used. Only fieldbus reconfiguration is needed in the secondary development. With this structure and proposed method, the CNC users who are very familiar with the CNC function requirements can easily do maintenance and secondary development at the shop floor level to realize new NC requirements. Also a case study is given based on the proposed structure and design method. The function maintenance and system upgrading of CNC system can be done in all its lifetime.

Key words: CNC, reconfiguration, Open, upgradable

INTRODUCTION

CNC system has been developed for more than 60 years. It plays an important role in industrial field as one of the core technologies. With the development of the manufacturing industry, small quality and customized manufacturing is gradually become the mainstream. The requirements of special machining functions are increasing as well. It demands more flexibility and reconfiguration ability of CNC machine tools. Therefore, open CNC systems for customized manufacturing are urgently needed. This is an old topic. CNC vendors and researchers also did a lot of work on it. Such as NGC and OMAC projects of the USA (Herrin, 1990), OSACA and OCEAN projects of European Union, OSEC project of Japan and ONC project of China. These researches are focused on the architecture of CNC system. The researchers tried to make standard interface between different modules to fulfill the demands of cooperate design. However, for the realization of different function modules, complex code programming and debugging is still needed.

Recent years, software modeling technology and component design theory has been maturely used in engineering. It brings new chances to the development of CNC systems. CNC system can be subjected to embedded real-time control system and has interactive characteristics. Its function is driven by internal or external events. The research on real-time interactive control system can give experience to the research of CNC system. For these kind of systems, D. Harel proposed an modeling method which is called Statecharts (Harel, 1987; Harel and Gery, 1997) . Statecharts is the extension of Finite State Machine (FSM) both on depth and width. It is very suitable for the modeling of complex interactive systems. A. C. Figueiredo Filho et al tried to simplify the embedded reactive system design with a statecharts driven kernel (Filho *et al*., 1993). It is a good method for reactive system. However, it is not suitable for complex system because the efficiency of the kernel and manual generated rule table. Liu *et al*., used Model Driven Design (MDD) to construct CNC system. With MDD method, the design burden can be eased. But the open ability is still limited in the design level. The CNC users who are very familiar with the CNC requirements do not have the ability to develop new CNC core functions. This caused two problems as follow:

- The lifecycle of CNC system was shortened. CNC system vendors have to always do upgrading of their product to fulfill the continuous appeared NC requirements. This brings a heavy burden to CNC system vendors
- It usually needs a long time for the CNC system vendors to fulfill the new CNC function requirements. A lot of special NC function requirements even can't get the support from CNC system vendors due to small market

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To resolve the two problems, a user-oriented secondary development ability of CNC core functions is urgently needed. In the previous research, a function separated design method is proposed by the authors (Hu *et al*., 2009). In this study, an all lifetime upgradable CNC control system structure and its implementation method are given based on the previous research. With this structure and proposed method, the CNC users who are very familiar with the CNC function requirements can easily do maintenance and secondary development of CNC system at the shop floor level to realize their new machining requirements. The function maintenance and system upgrade of CNC system can be done in all its lifetime.

ALL LIFE-TIME UPGRADABLE CNC SYSTEM STRUCTURE

To fulfill the requirement, a CNC system structure which is fit for user-oriented secondary development is proposed as shown in Fig. 1.

In this structure, a fieldbus technology is adopted as the design platform because of its reconfigureability and the CNC controller is implemented in the fieldbus master. CNC controller is designed as five parts: HMI, Shared Memory Access Lib, Function modules, Scheduler/Distributor and Fieldbus Driver. With this structure, Function Module is designed as separated parts. Different applications can be derived by redesign of Function Module. A Scheduler/Distributor is designed as a bridge between Function modules and Fieldbus Driver. Sampling data received from slaves is packed as event and then been sent to function modules. Function modules process these events and the processing result is sent to scheduler/distributor and then the fieldbus driver as command data. Shared memory is used in this structure. The communication between function modules, as well data exchange between function module and HMI are realized with shared memory.

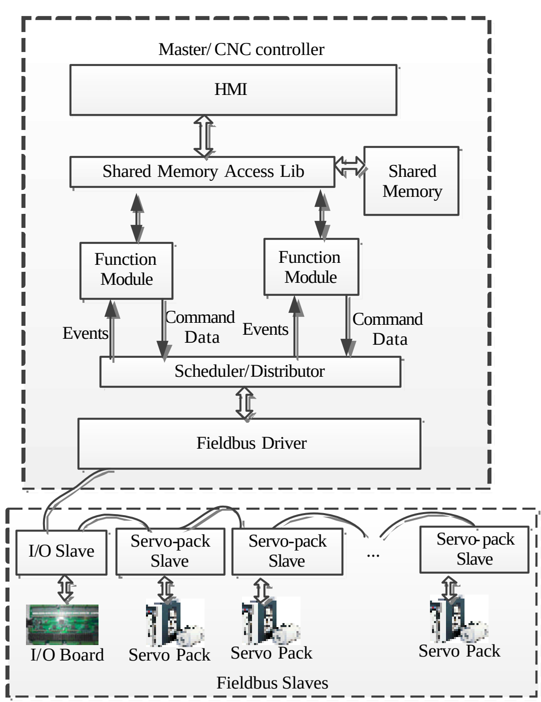

Fig. 1: System structure

PLATFORM IMPLEMENTING METHOD

Implementation of HMI: In the structure proposd in this study, HMI must be designed to fit all different application cases. In order to guarantee its open ability, the HMI is designed as Fig. 2. In Fig. 2, the HMI is designed as Fig. 2. In this structure, control model (e.g., G/M Code, Manual command) is input from GUI/Operation panel interface or OPC interface, Auto Task Generator and ManuCmd Generator is then be called to generate auto task and manual command. By calling functions of Shared Memory Access Lib, the generated command is sent to Function Modules. Also system status can be derived from function modules by calling functions of Shared Memory Access Lib. OPC interface is designed to communicate with remote manufacturing units. With the Shared Memory Access Lib, HMI can be openly designed to fulfill all different application cases.

Implementation of function modules: Every function module is designed as Fig. 3. In this figure, Function Module is designed as two parts, Function Description Data and General Process Engine. Function Description Data is designed like a dictionary. Once the event is received by General Process Engine, it looks up the Function Description Data to find the processing method. And with the processing method, it then generates control command data

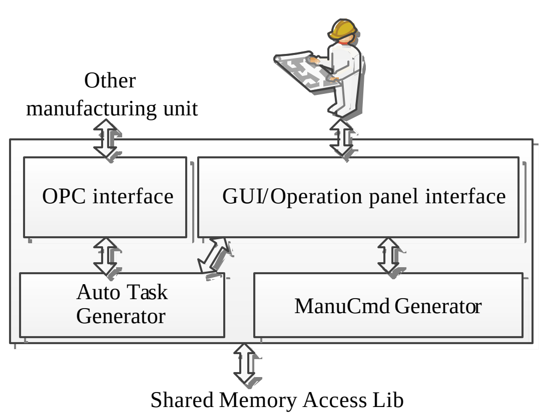

Fig. 2: Structure of HMI

and sends it to scheduler/distributor and then fieldbus driver to drive actuators.

In the previous research (Hu *et al*., 2009), Function Description Data is generated by Statecharts modeling. With the FDD generator, Function Description Data can be graphically modeled. With this modeling method, Different machining functions can be easily derived and updated at shop floor level.

The implementing scenario of Function modules are designed as Fig. 4. When the system starts, according to the description of Function Description Data, a mutiway tree is generated to describe the system function by the General Processing Engine. By marking the joint status of the mutiway tree, the system status can be represented. When the General Processing Engine processes events sent from scheduler/distributor, it queries the mutiway tree to get the event processing method. By joint traversing, joint activation and joint deactivation, the system status can be updated, also the processing method can be derived.

With this design, the CNC function description can be separated from the complex system. CNC function updating and modifying can be easily done by re-generation of Function Description Data.

Scheduler/Distributor and fieldbus driver: The Scheduler/Distributor is designed as a bridge between Fieldbus Driver and Function Modules. Fieldbus Driver sends/receives event/command to/from Scheduler/Distributor. Different fieldbus can formalize different drivers. A mapping table is designed in Scheduler/Distributor. When the event from the Fieldbus Driver comes, it packs and sends the event to specified function modules according to the mapping table. Also the scheduler/Distributor processes the control command generated by the function modules and sends it to Fieldbus Driver to drive actuators.

IMPLEMENTING SCENARIO OF ALL LIFETIME UPGRADABLE CNC SYSTEM

With the structure proposed in Fig. 1, an all lifetime upgradable CNC control system design scenario can be implemented as Fig. 5.

As shown in Fig. 5, after user requirement analysis and CNC application environment analysis, the CNC function structure is designed. According to CNC function structure, software and hardware design will then be done separately. With the integration of hardware and needs to be developed. In this system, the parts geometry

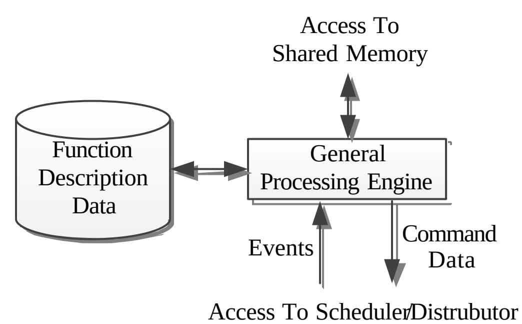

Fig. 3: Structure of function modules

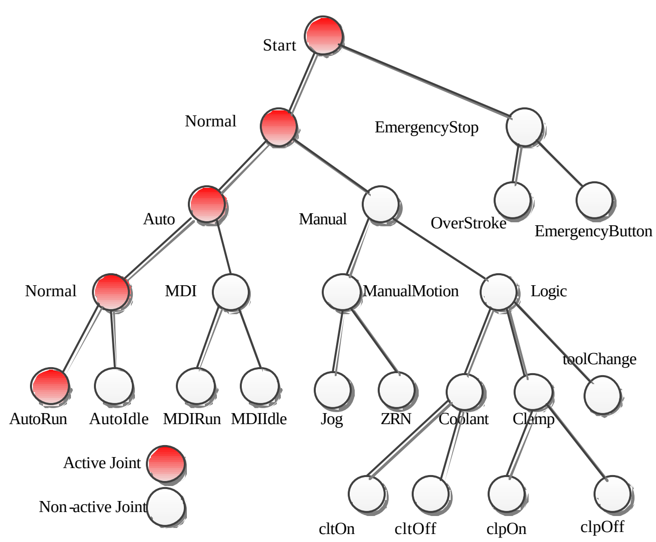

Fig. 4: Multiway tree description in general processing engine

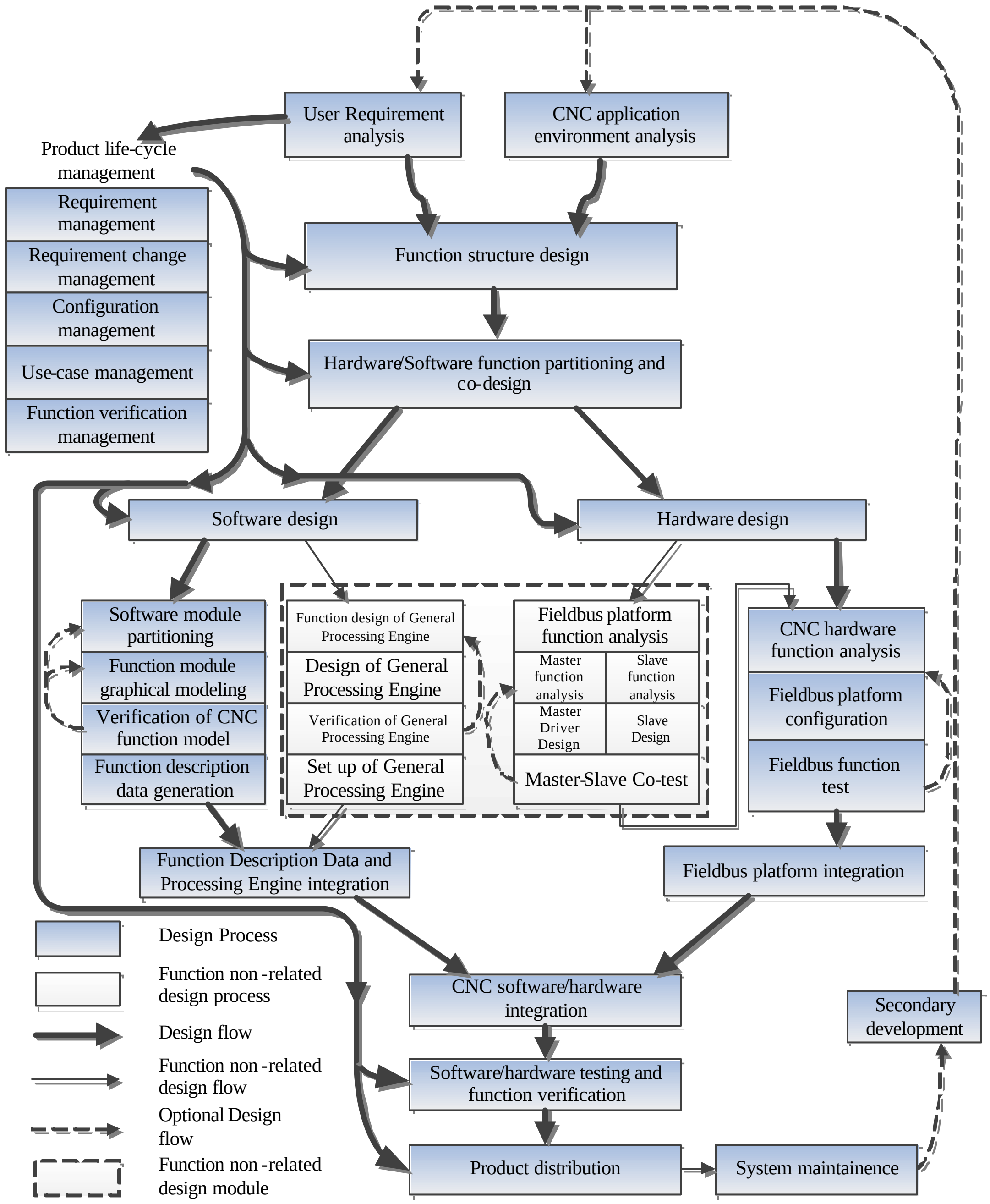

Fig. 5: All lifecycle upgradable design method of CNC system

parameters are derived from their factory management system. G/M Code can be automatically generated with these geometry parameters. And also machine tool status, such as alarm information, electrical power cost are required to be transferred to the factory management system. Fig. 6 shows the existed roller grinding CNC system and the required roller lathe CNC system.

Implementation: To develop the required roller lathe CNC system based on the roller grinding CNC system, the required works are as below:

- Hardware reconfiguration. An X Axis Servo Pack and related I/O information should be added. As shown in Fig. 5, after adding an X Axis servo pack into the

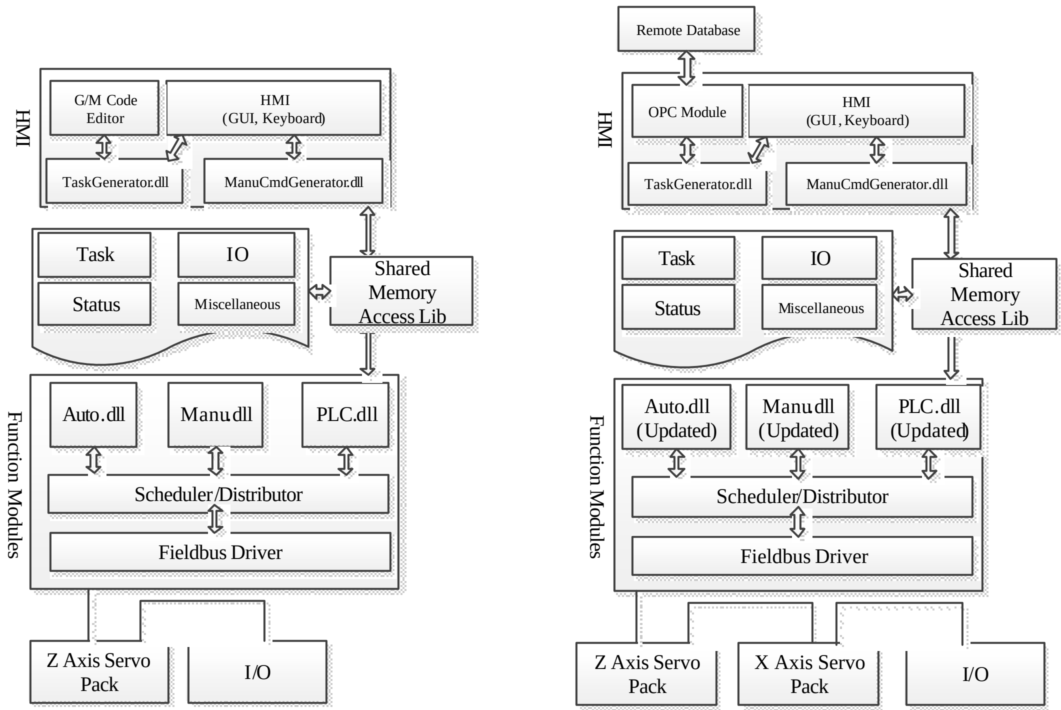

Fig. 6(a-b): (a) Existed Roller Grinding System and (b) Required Roller Lathe System

fieldbus platform, only fieldbus reconfiguration and relevant test is needed. The hardware platform of Roller Lathe system can be easily derived based on the existed roller grinding system

- Development of software. New control functions such as two axes interpolating functions, manual operation related to Axis X and new HMI functions such as OPC module which in charge of communication with upstream database, new HMI interface need to be updated or redeveloped. Following the scenario of this study which shows as Fig. 5, the new control functions and HMI functions can be easily added/replaced and then the software of Roller Lathe System is derived

CONCLUSION

In this study, an all lifetime upgradable open CNC system structure is proposed as well as the design method. With the proposed structure, the system is divided into function related design and non-function related design. The secondary development and function upgrading of CNC system can be easily done via function-related design process. The software function-related design can be fulfilled by graphical modeling and verification and hardware function-related design can be finished with fieldbus reconfiguration. With the proposed method of this study, new function or function upgrading can be easily done in the shop-floor level. The life-cycle of CNC system is extended and also the new CNC function requirement of special machine tool market can be fulfilled in a short time.

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