A Framework for Intelligent STEP-NC Controller Based on Multi-agent

Hongbo Lan[1,2], Chengrui Zhang[1], Riliang Liu[1]

[1]School of Mechanical Engineering, Shandong University, Jinan, 250061, China
[2]School of Mechanical Engineering, Xi'an Jiaotong University, Xi'an, 710049, China

Abstract

This paper presents a conceptual framework of STEP-NP controller to implement intelligent control for CNC machine tool. This framework is developed based on the concept of multi-agent systems, and derived from the detail analysis of process flow and the specific requirements for intelligent STEP-NC controller. The architecture of intelligent STEP-NC controller is composed of four layers: application service layer, data and knowledge layer, operating system layer, and target hardware layer. The application layer consists of fourteen functional agents which involves the interpreter agent, process planning agent, NCK/PLC agent, decision-making Agent, etc. These agents can cooperate closely to carry out various functions of intelligent STEP-NC controller in a well manner. As a result, the framework proposed provides a paradigm for future implementation of intelligent STEP-NC controller.

Keywords:

Intelligent, CNC, STEP-NC, Multi-agent

1 INTRODUCTION

The aim of next generation CNC system is to be intelligent, network, portable, interoperable and adaptable. However, the current data interface for CNC based on ISO 6983 is a low-level language mainly specifying the cutter motion in term of position and feed rate. There are a number of problems found for this data interface, which are summarized as follows: delivering limited information to CNC, transferring one-way information from CAD/CAM to CNC, unable to implement the seamless integration of the CAD-CAM-CNC, etc [1]. Furthermore, the next generation CNC is developing toward the intelligence, network and software-based open architecture. All require urgently a new data interface replacing the current ISO 6983. Today, a new interface standard, recognized informally as STEP-NC, is being developing by ISO TC184 SCI and SC4, and is formalized as ISO 14649 and ISO 10303 AP 238. As a new model of data transfer between CAD/CAM systems and CNC machines, STEP-NC overcomes the shortcomings of ISO 6983 by specifying machining processes rather than machine tool motion, using the object-oriented concept of Workingsteps which correspond to high-level machining features and associated process parameters [2]. The new interface scheme will impact strongly the CAD-CAM-CNC process chain and the advance of the CNC controller. Since the new language accommodates rich information, the STEP-compliant CNC can implement various intelligent functions and decision-makings activities which cannot be performed by the conventional CNC operated based on ISO 6983. Therefore, STEP-NC shows a high potential to fulfill the intelligent control for machine tools by a new breed of STEP-NC controller. As the new standard is established, increasing attention is being paid to the development of a new generation intelligent controller based on STEP-NC. This paper presents a conceptual framework of STEP-NP controller to implement intelligent control for CNC machine tool.

2 ARCHITECTURE OF INTELLIGENT STEP-NC CONTROLLER

Based on involving different functions, Intelligent STEP-NC controller can be divided into three types: (i) Autonomous STEP-NC controller, (ii) Autonomous and Collaborative STEP-NC controller, (iii) Holonic STEP-NC controller. In this paper, our research focuses on the Holonic STEP-NC controller. The process flow of the intelligent STEP-NC controller is different from the conventional CNC system. Figure 1 describes the process flow of intelligent STEP-NC controller.

Step1: The operation is initiated by inputting the STEP-NC file of a part to the controller.

Step2: The controller would convert the STEP-NC file into an internal data format and store the information contents in the part information DB by interpreter module.

Step3: Various technological data such as file head, feature, process, tolerance, etc., need be further extracted from the STEP-NC file for following processes.

Step4: Process planning is performed subsequently to determine the processing sequence, operations fixture,

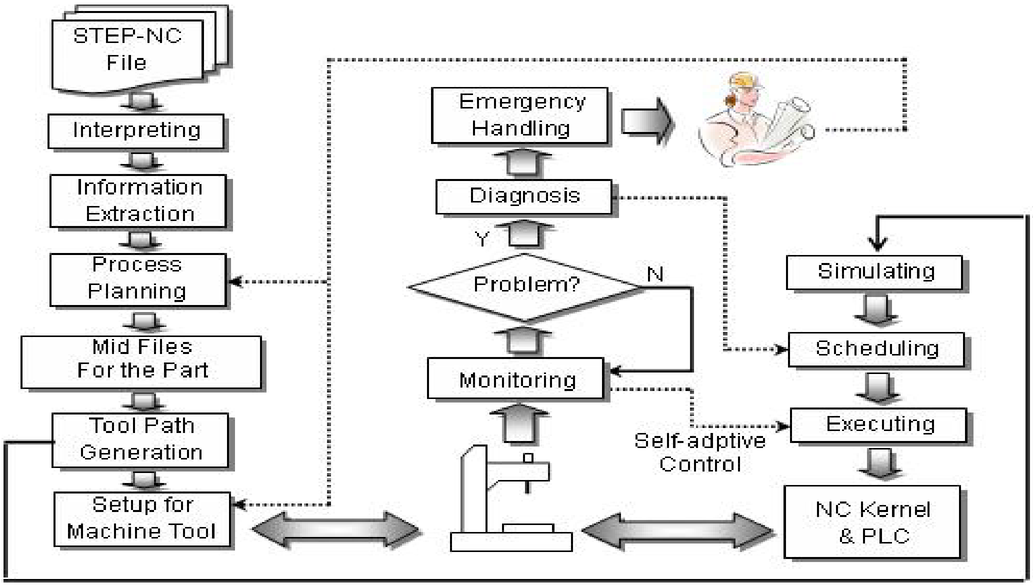

Figure1: Process flow of intelligent STEP-NC controller

set-ups and cutting tools required to machine the features of a part. The conventional scheme may be often based on the off-line process planning method. However, the off-line planning method can not meet the requirements of intelligent STEP-NC controller. In order to implement the dynamic process planning, intelligent control and bi-directional data flow, a new method of process planning which consists of off-line planning, on-line planning and teal-time planning was proposed to carry out the process planning functions for the intelligent STEP-NC controller.

Step5: After completed process planning, some mid files are to be generated and stored a File Database.

Step6: The main function for tool path generation is to create the actual machining trajectory of tool for each Workingstep according to machining feature, operating as well as machining strategy, etc. A completed path including approach, departure, and connection path can be determined and store a temporary DB.

Step7: Prior to actual machining, it is necessary to perform a cutting simulation to verify the given tool path and to detect any possible errors. The simulation module can aid to find out undercut or tool interference by cutting simulation.

Step8: When the parameters setup for machine tool and simulation process are completed, a scheduling (or decision-making) will be executed. It schedules a performing task, and determines the next task from various alternatives. For scheduling process, one of the critical functions is to assign the priorities between the scheduled task and the newly invoked task by the monitoring and diagnosis module.

Step9: Executing operation converts the scheduled tasks into commands and passes on them to NCK/PLC. If the task is a machining operation, it retrieved the corresponding tool path from tool path DB and passes it to NCK/PLC. If the task is a tool change, find the tool in the tool magazine and passes it to NCK/PLC.

Step10: NCK interprets the tool path commands and executes them by activating the servo mechanism, and PLC carries out machinery commands, such as tool change and workpiece loading/unloading. New interpolation algorithms need be developed.

Step11: The entire machining status is continuously monitored by capturing information from sensors. Tool monitoring and emergency detection are critical tasks. The obtained results are sent to the diagnosis module.

Step12: According to the diagnosing results, to remove various malfunctions. If a failure could not be obviated, or in case of an emergency, the diagnosing module will send an urgent signal to emergency handling module and operator.

Based on the above analysis of process flow for intelligent STEP-NC controller, each functional module in STEP-NC controller can not only work independently but also cooperate closely to carry out various functions of intelligent STEP-NC controller. Functional units may affect other units or may be affected by other units or even operator. If utilizing conventional control strategies, it is especially difficulty to fulfill various functions of intelligent STEP-NC controller in a well manner. Multi-agent technique offers a better implementing solution [3, 4]. Based on the MAS principle, each functional module in STEP-NC controller can be considered as an agent, these agents

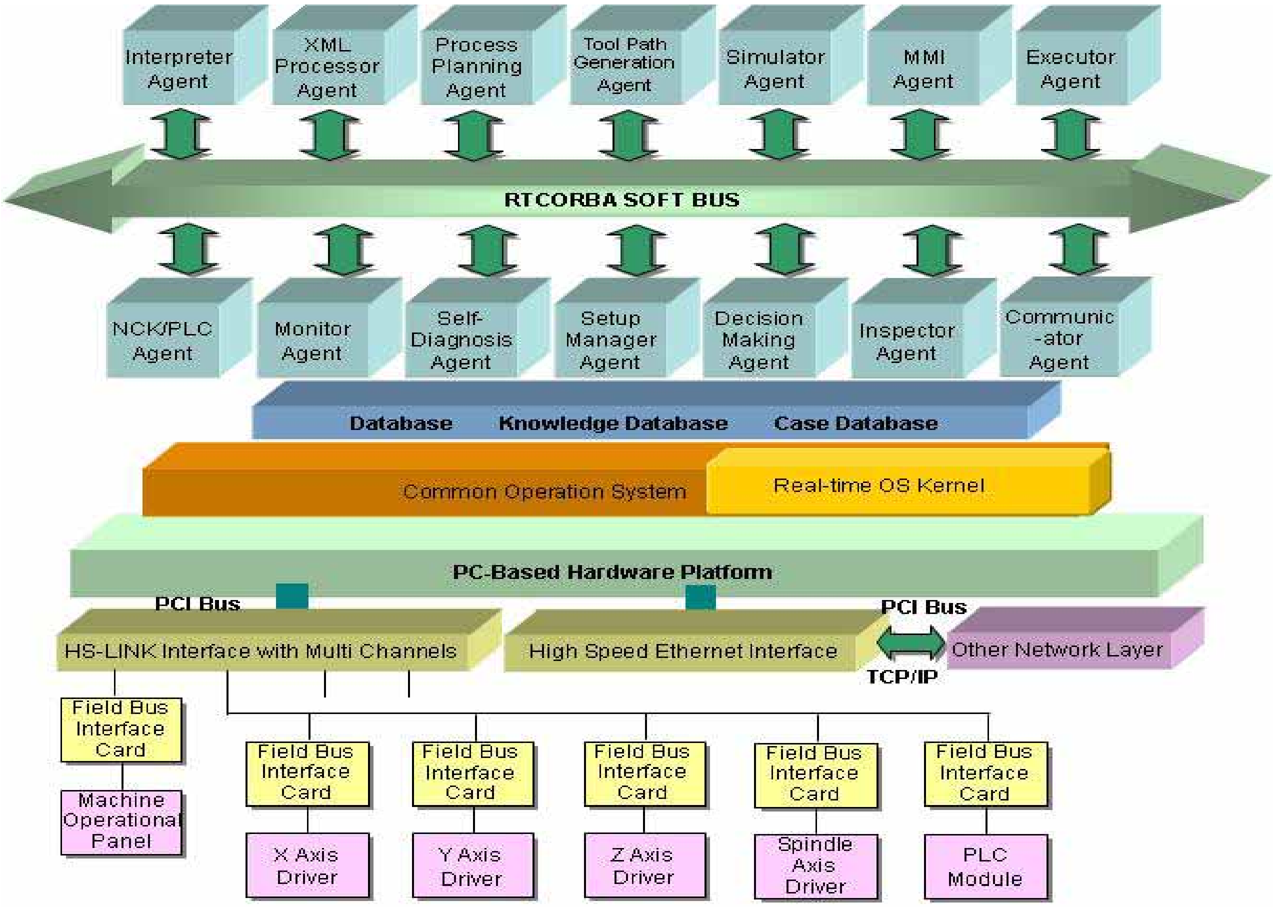

Figure 2: Architecture of intelligent STEP-NC controller based on multi-agent

(functional units) can cooperate closely to carry out various functions of intelligent STEP-NC controller. In addition, the development of new STEP-NC controller should consider meeting the requirements of next generation CNC. The aim of next generation CNC is to be intelligent, network, portable, interoperable, adaptable and software-based open architecture. It is believed that CNC machines implementing STEP-NC will be the basis for a more open and adaptable architecture. Based on the detail analysis of process flow and actual functional requirements for intelligent STEP-NC controller, combined with the concept of multi-agent system, this paper proposed a conceptual framework of holonic STEP-NP controller based multi-agent to implement intelligent control for CNC machine tool, as shown in Figure 2. The architecture of intelligent STEP-NC controller is composed of four layers: application service layer, data and knowledge layer, operating system layer, and target hardware layer. The application layer consists of fourteen functional agents which involves the interpreter agent, process planning agent, NCK/PLC agent, decision-making Agent, etc. The functional details for each agent are described in detailed below.

(1) Interpreter Agent. The interpreter agent is able to read STEP-NC files (ISO14649 or AP238), convert them into an internal format, recognize and extract machining features. Output is stored in the machining feature Database.

(2) XML Processor Agent. To implement web-based manufacturing, the XML processor is to handle data files in an XML format to use STEP-NC in XML data file. It includes two parts: the XML editor and the convector. Data written in XML format in a STEP-NC program have XML structure and are consistent with the STEP-NC schema. The converter changes links in part 21 to the branches of XML, and adds tags to increase efficiency for data handling. The agent is currently optional, and to be developed and integrated the holonic STEP-NC controller in the future. (Note that the input of above process flow is STEP-NC file, not STEP-NC XML)

(3) Process Planning Agent. This agent is to determine the processing sequence, operations, fixtures, set-ups and cutting tools required to machine the feature. For the STEP-NC controller, a process plan is primarily responsible for the following tasks: (i) assign machining operation for each machining feature; (ii) setting up process parameters for the assigned machining operation; (iii) determining Workingsteps; (iv) classifying the Workingsteps into several groups according to the setup; (v) sequencing the

Workingsteps.

(4) Tool Path Generation Agent. The agent is to generate the actual machining trajectory of tool for each Workingstep according to machining feature, operating as well as machining strategy, etc. Various new algorithms based on feature need to be developed.

(5) Simulator Agent. The simulation agent is used to visualize and verify the optimized tool path and to detect any possible errors before a real-time machining.

(6) Man & Machine Interface (MMI) Agent. This agent manages and operates the Database component, MMI component, and system configuration component.

(7) Executor Agent. It converts the scheduled task into commands and passes on them to NCK/PLC.

(8) NCK/PLC Agent. NC kernel implements motion planning, velocity control, position control, trajectory interpolation, spindle control, PID control, and other management functions of motion control. PLC is responsible for various logical control functions in STEP-NC controller including tool change, workpiece loading/unloading, cooling and lubricant system control, etc.

(9) Monitor Agent. To monitor the entire machining process, once an abnormal status is to be detected, the agent will promptly send signals to the diagnosis module.

(10) Self-diagnosis Agent. Based on the message from monitor module and the actual status of current machine tool obtained from various sensors, the diagnosis agent would determine the type of different malfunctions, and remove them utilizing the self-repairing function of the controller. If a malfunction could not be obviated, or in case of an emergency, the diagnosing module need send an urgent signal to emergency handling module and operator.

(11) Setup Manager Agent This agent is to set and automatically adjust various parameters for machine and workpieces.

(12) Decision-making Agent. The decision-making agent is responsible for managing all agents' activities. The task scheduling is a key sub-module which schedules the task, and determined the next task from various alternatives. As another critical sub-module, cooperative sub-agent can implement close cooperation among multi agents, and solve their collision. The emergency handling function is also integrated the decision-making module.

(13) Inspector Agent. The inspector agent is to measure the geometric accuracy of the machining part. The inspection operation is considered as a Workingstep. The agent is optional now.

(14) Communicator Agent. Communication is one of the major characteristics that must be considered in the design of multi-agent systems. It fulfills the interactions with internal multi-agents, and the external units, such as sensors, actuators, CAD/CAM system, and operator.

Combined with operating system including real-time OS kernel, PC-based hardware platform, and various Databases (e.g. machining feature DB, tool path DB, machine resource DB, etc), Machining Knowledge Database, and Case DB, these agents can cooperate closely to carry out various functions of intelligent STEP-NC controller in a well manner.

3 CONCLUSIONS

This paper proposed a multi-agent-based conceptual framework for future implementation of intelligent STEP-NC controller. The architecture is composed of four layers: application service layer, data and knowledge layer, operating system layer, and target hardware layer. The application layer consists of fourteen functional agents which can cooperate closely to carry out various functions of intelligent STEP-NC controller in a well manner. The conceptual framework provides a paradigm for future implementation of intelligent STEP-NC controller.

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