APPLICATION OF HIERARCHICAL MODEL METHOD ON OPEN CNC SYSTEM'S BEHAVIOR RECONSTRUCTION

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Abstract: There are many shortcomings in the open CNC system control program developed by the traditional programming mode, such as maintenance difficulties and poor portability. The application and development of FSM in CNC system are researched in this paper, and the basic principles of FSM and reconstruction mechanism of FSM are introduced. The reconstruction process based on FSM by the application of hierarchical modeling method and status table are also constructed. At last, the adaptive control function of automatic adjusting feeding speed in three axis CNC milling machine is extended to realize the function definition of the software unit in control system and control logic separation.

1 INTRODUCTION

NC system is an abbreviated form of numerical control system. It is a complex multi-tasking controller with different levels of real-time requirements. In the system, each object's function, behavior, starting process and their mutual relationships between the operating system modeling must be a clear description. This is directly related to the system's performance and operating reliability. Kruth et al. (2001) use FSM to model the planning and monitoring knowledge in Machine tool control. Li et al. (2005) apply a hierarchical finite state machine to the system behaviors' model o improve the reconfigurability in an open architecture control system. Ma et al. (2007) propose a dynamical behavioral modeling and describe it in hierarchy finite state machine model. Aiming at the characteristics of modularity and reconfigurable in open architecture computer numerical control (CNC) system, Wang et al. (2007) adopted finite state machine to create the dynamically modeling. Lid et al. (2008) use hierarchic finite state machine to describe dynamical behaviors of the controller. Using FSM method, the machine control flow can be separated with the mechanical parts, and it can be changed separately. This approach greatly increases the openness of the CNC system by limiting the control program which depends on the particular machine behavior and operating in a local part. Based on the working principle and the hierarchical modeling method of finite state machine, we create the model of complex system to explore the application of finite state machine in numerical control system software development process.

2 THEORETICAL BACKGROUND

2.1 Finite State Machine

Finite state machine consists of the following elements:

1) State: The basic component of behavioral model. It reflects the stage and activity of an object in the system.

2) Transfer: The process from one state to another state of the objects.

3) Event: The events and conditions that caused the state transformation of object.

4) Action: The action of object when the state changes.

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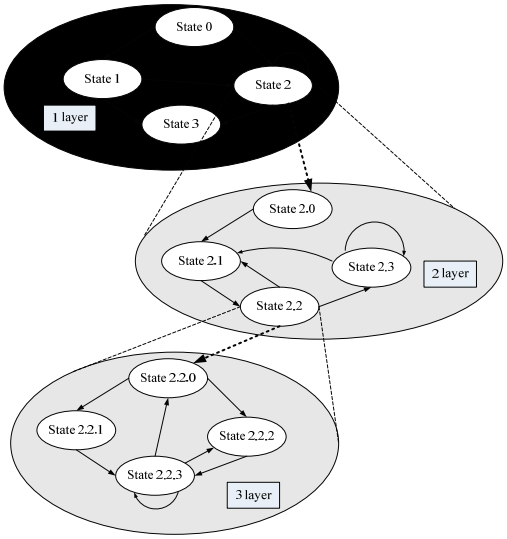


Figure 1: Hierarchical FSM model denotation for system behaviours.

For complex systems, such as using the above basic FSM model, there may be hundreds of the state, resulting in decreased efficiency of the system, and it is difficult to validate and maintain the system. Therefore, we need to expand the basic FSM model to be a hierarchical FSM model. In figure 1 using hierarchical modeling can make the system in a structured, hierarchical expression(Pritschow, Sperling, 1993).

2.2 State Table

Open CNC system's FSM consist of state set, event set, transfer set and action set, we call this state table (Wang, 2003).

State table can be used linked list structure. In the linked list, each unit contains a state sign and a pointer points to the transfer set. The structure of the state table as shown in Figure 2, every state has a number of transfers. In figure 2, state 7 is the composite state, which corresponds to the state of 7.1 and 7.2 in the lower layer of FSM.

When the needs of the system's changes, the system behavioral changes, such as add, delete, and replace in the state table. In figure 2, we replace "`action 3()`" with "`modifiedAction ()`", add a newState, new transfer "`&tran7`" and new event "`newEvent1`". Through the modification of the state table, we can reconstruct the system which is based on FSM.

In order to create and revision status table, the FSM-based class library can be used. The class library not only provides the API of state table's definition, query and modify, but also can be the drive center of FSM. Based on the current state, the class library finds the corresponding transfer, trigger required routine, so as to realize the system's specific functions.

3 MODULE DESCRIPTION AND RECONSTRUCTION PROCESS BASED ON FSM

3.1 Systems Module Description

CNC software is a real-time and multitasking software, it has two types of tasks: management and control. System management section contains input, I/O process, display, diagnose, etc. The control section contains decoding, cut adjust, speed processing, interpolation, position control, etc. Interpolation and position control is a real-time task. Decoding, cut adjust and speed processing is a condition task. The software should ensure synchronization between tasks.

The of function modules of a numerical control system include: Coordination Module, Pretreatment module, PLC module, Interpolation module, Motion control module.

Take the three coordinates CNC milling machine as an example, the simplified FSM models of coordination module, interpolation module and motion control module are shown in figure3.

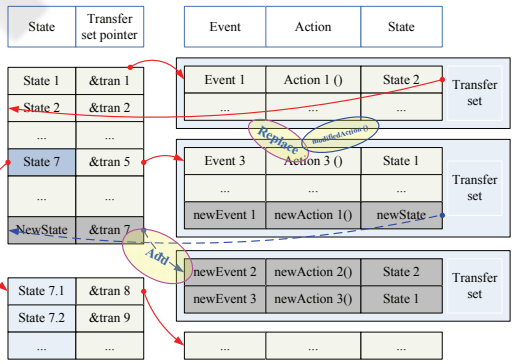
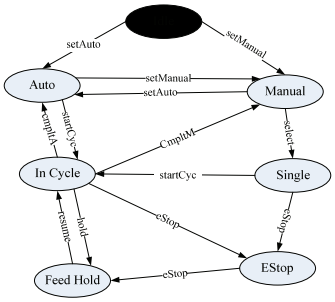
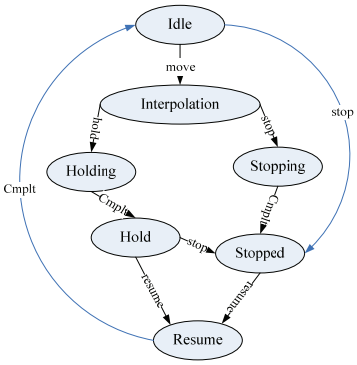


Figure 2: Structure of state table.

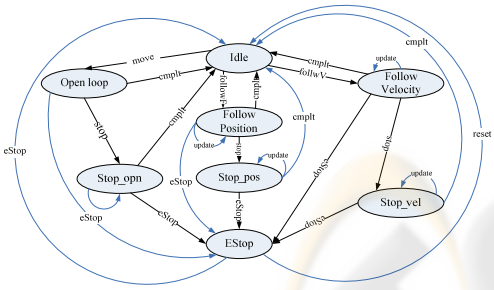
The complete FSM is formed by all the modules together according to the hierarchical structure. Task coordinator is dispatch center of the control software, and FSM is located in the top-level of the system. Other modules run in parallel under the management of FSM.



a: Coordination module.



b: Interpolation module.



c: Motion control module.

Figure 3: Simplified FSM models.

3.2 Flow of Reconfiguration

From the perspective of FSM, a new control flow and parts reconstruction means state, transfer, event and action's change. And this information is described with a state table which is not dependent on the system. Consequently, the reconstruction of the system means that the reconstruction of FSM's state table. Figure 4 shows the flow of reconfiguration system with FSM.

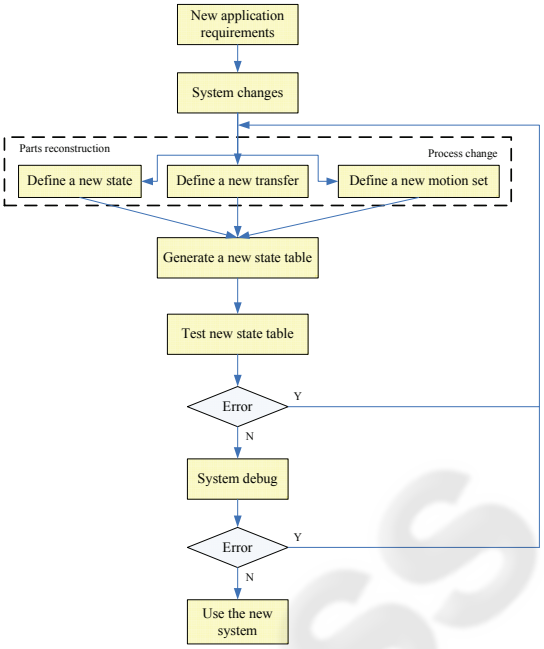


Figure 4: Flow of reconfiguration system with FSM.

4 THE CASE STUDY OF OPEN CNC SYSTEM'S FUNCTION EXPANSION

The following example is to expand the adaptive control function of automatic adjusting feeding speed in the three axis CNC milling machine. Due to adopted FSM model, only motion control module related with the motion control needs to modify in the system, and the other modules are no need to change. This method greatly reduced the system function expansion of programming workload.

As shown in figure 5, the modification of state table is consisted of adding a state of `"Velocity_Adjust"`, a transfer related with adjustable speed and a transfer related with the state of `"Follow_ Velocity"`. These new entries can be created with the method of `addTransition` provided by FSM-based class library. This function prototype is: `CFiniteStateMachine :: addTransition (string state, string event, string nextState, CFSMAction action)`.In this function, `CfiniteStateMachine` indicates the class of FSM. For example, `string` indicates a string class, `state` indicates the name of object's state, `event` indicates the name of the events that object received, `nextState` indicates the name of the next state that object will transfer, `CFSMAction` indicates action class of FSM, `action`

indicates the action triggered in the transfer process of object.

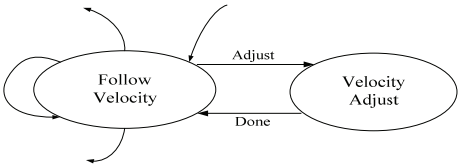


Figure5: Change of FSM state.

As shown above, it is very convenient and efficient to change status table with the method provided by FSM base class library. In addition, module developers still need to complete the programming of `AdjustAction` and `DoneAction`.The following is part codes of `AdjustAction ()`, it can realize the function of speed adjustment.

Currently popular adaptive speed control algorithm can be added in the above codes to satisfy all kinds of needs of users. According to adding speed regulating adaptive control functions in three axis CNC milling machine, the open CNC system can integrate other external sensor signals to implement users' unique control strategy.

5 CONCLUSIONS

As the dynamic behavior model of the system, FSM has the ability of behavior reconstruction. This method greatly increases the openness of the system. The model of behavior which is based on finite state machine stipulates the system behavior and control flow, cuts down the development cycle of the CNC system and enhances the reliability of the system. At the same time, FSM model can realize the function definition and control logic separation of software unit. It can improve flexibility of system reconstruction. Finally, the system's reconstruction based on finite state machine represents the reconstruction of state table. This can simplify the reconstruction process of the numerical control system absolutely.

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