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Open CNC machine tool's state data acquisition and application based on OPC specification

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Abstract

For open CNC machine tool, user can develop third-party software based on OPC specification. Besides, CNC machine tool produce massive state data in machining process, which real time reflect the states of the machine. In this paper, the structure of open numerical control system is introduced, then data acquisition and compression based on OPC specification is implemented, finally data mining of the status data and its application in the intelligent fault warning and diagnostic is proposed. This research is critical to realize the digit and smart factory.

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Keywords: open CNC machine tool; OPC specification; data acquisition; fault warning; data mining

1. Introduction

The fault of CNC machine often occurs in the machining process. In order to reduce the failure time, improve the production efficiency, and realize the digit factory, monitoring the state variables such as spindle current, motor temperature, vibration signal, motor load and power, which indicates the performance of CNC machine tool in machining process is an effective method[1]. And the data analysis can be used in fault warning, fault diagnosis, and predicting the machining accuracy. So it is a basic work to study the method of data acquisition. At present, researcher mainly focused on the following ways: based on external hardware or commercial software or OPC specification.

Communication grabbers such as CP5511, CP5611 and CP5613 which developed by SIEMENS can exquisite the state data and realize the communication access with PLC, it was widely used in the past[2]. R. Coelho at University of Sao Paulo in Brazilin has installed the acoustic pressure sensor and voltage sensor on CNC machine, via Labview software return the acquisition signal and obtained the state data by NetDDE server. Finally, assess the workpiece error though the cutting tools wear[3]. SinCOM software launched by SIEMENS can solve the problem of state data exchange between numerical systems and remote host with RPC function[4]. While the Siemens series machine supports OPC specification, the third party applications in HMI can follow OPC specification to obtain state data, this method has become a hotspot[5].

2. The mechanism of data acquisition

2.1. The structure of CNC machine and acquisition method

(1) The structure of CNC machine tool

The hardware structure of SINUMERIK consists of HMI, NCU and PLC. The software system is composed of HMI advanced that operate in MMC, the NC software in the NCU, the PLC systems and the driver interface software. The associated data are stored in different locations, such as the MMC hard disk, RAM of the NCK, EPROM and PCMCIA card, RAM of the 611D. The data communicate and operate though the DPR function (two ports RAM). The data storage structure of CNC machine tool as follow Fig.1.

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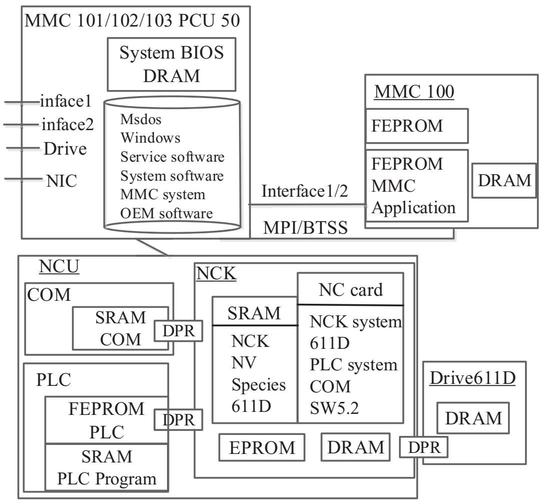

Fig.1. Data storage structure in CNC machine tool

(2) Data acquisition methods

In Fig.2, it can be seen that the transmission of the state data between HMI and the control unit NCK just via the interface NCDDE server. Besides, data exchanging and file interaction between HMI applications and NCDDE server have two methods: one of that is the DCTL control, another one is OPC/ Sinumerik server.

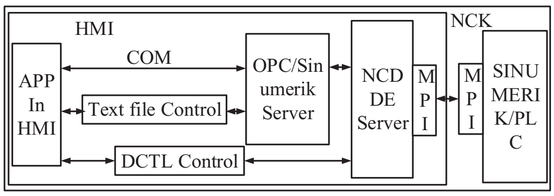

Fig.2. The interface of Siemens control system

DCTL is an ActiveX control which is used to establish data exchanging communication between the HMI software and the NCDDE server. It occupies a little windows sources, closer cooperation with NCDDE sever and the faster transform speed.

Achieving data acquisition through the OPC specification can eliminate unnecessary hardware and pretty cost-effective. Take the SIEMENS CNC system into consideration, finally decide to develop acquisition software based on OPC specification.

2.2. The OPC specification support of the SIEMENS system

OPC specification which based on OLE/COM/DCOM technology is applied to object linking and embedding in the process control. It defines the mechanism of data exchange among PC clients and supplies the C/S mode standard for the industrial automation software.

OPC specification module includes three objects: one of that OPC Server can get the initial class and maintain the information of other objects; another one OPC groups provides inclusive and logical organization mechanisms for the variables; the last one OPC items represent the specific name of the state data. The relationship between three objects and the content of OPC server is shown in Fig.3.

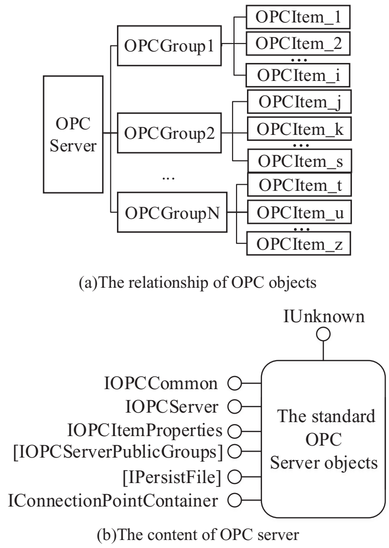

Fig.3. The OPC objects

The HMI of Siemens CNC machine tool installs two type of OPC Server: data access server and alarm event server. In HMI system folder the installed position and configured information can be seen. In order to get the data on the client from the OPC server, user need to clearly recognize the OPC items. While the OPC server isn't supported to traverse, so developer must clarify the CNC machine tool's variables which can be read.

In Siemens numerical control system, all variables are divided into eight parts, the detail region information as the Fig.4. In each area it will be subdivide into different data module.

For example the axis-specific basic variable is divided into the machine data and setting data. The variable "MMD_SPIND_MAX_VELO_LIMS" is located in the subclass module of setting data, whose full name is: /Axis/Settings/MMD_SPIND_MAX_VELO_LIMS [u<Area index>], where <Area index> indicates the number of specific axis.

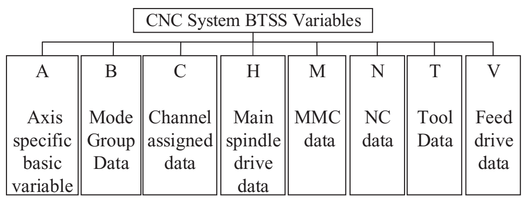

Fig.4. Region information about system variables

3. Realized the data acquisition and compression

3.1. The Realization of OPC acquisition client

The OPC acquisition client includes two mainly functions: configuring system variables and the state data acquisition. Configuring the system variables provides a flexible monitor selection which can help users to develop monitoring programs according to the site needs; the state data acquisition is a key components which is the foundation of the remaining work. The mainly modules and their interrelation of OPC acquisition client as below Fig.5.

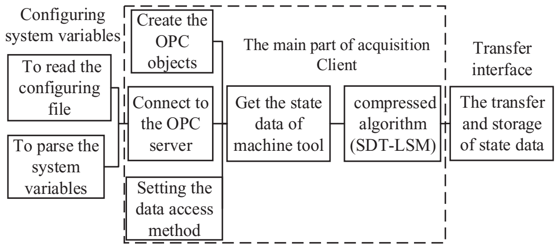

Fig.5. Main modules and their interrelation in OPC client

Configuring system variables be in charge of parsing the variables file on the numerical control system and extracting the variables into an array, which is the corresponding OPC items. State variables are stored in .txt text, each rows represent the specific variables.

Data acquisition parts includes the OPC objects creation, parameter setting and data returning. Firstly the Siemens OPC automation interface functions should be referenced otherwise there will be error warning. And the object of OPC server should be instated and connected, after that OPC groups and corresponding OPC items will be created in the instantiation server.

The critical code as follows, where OPC.SINUMERIK. Machineswitch is CLSID identifies of Siemens OPC Server.

```
OPCServer Sserver=new OPCServer ( );
Sserver. Connect ("OPC.SINUMERIK.Machineswitch");
Sgroups=Sserver.OPCGroups;
Sgroup_fast=Sgroups. Add ("Group_fast");
Sitems_fast=Sgroup_fast.OPCItems;
```

Next users need to set the parameter properties such as the data access method, the state of OPC groups and update rates. In particular, setting the OPC objects activation or not, default dead section, whether it can be subscribed. The code as follow:

```
Sserver.OPCGroups.DefaultGroupIsActive = true;
Sserver.OPCGroups.DefaultGroupDeadband = 0;
Sgroup.UpdateRate = 100;
Sgroup.IsActive = true;
Sgroup.IsSubscribed = true;
```

Then the display method of state data on the interface should be settled. This paper adopts the subscription way to renew the data. When the OPC server has changed, the data-change function will be trigged and returned the corresponding value of OPC items. The process of acquisition software as below Fig.6.

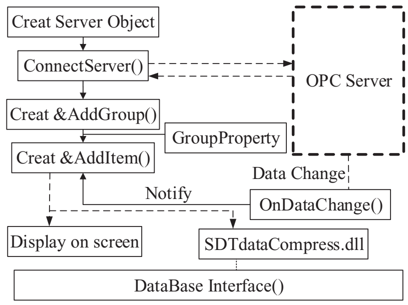

Fig.6.Process of acquisition software

3.2. Data compressio algorithm (LSM-SDT)

The number of the state data is enormous. Hence there need compression algorithm to reduce the resource of database, and ensure that these data can reflect the true history of the CNC machine tool after reduction. Swing Door Trend algorithm is a fast linear fitting method with higher compression rate and controllable error[6]. Firstly, defining the compression ratio *CR*, and the recovered absolute error *AE*:

$$CR = \frac{n}{m} \quad (1)$$

Where n, m are respectively the dimension of the original data and compressed data.

$$AE = \sqrt{\frac{1}{n}\sum (y_i - y_i^{`})^2} \qquad (i = 0,1...n) \quad (2)$$

Where y_i is the original data, $y_i^{'}$ is data points that recovered from the compressed data.

As seen in Fig.7, point *B* is the first one that needs to be compressed. According to the former point *A* and the tolerance ΔE, two pivot positions A_1 and A_2 of the Swing door can be determined. Then two doors will be expanded, the slope of the line A_1B keep the maximum and the line A_2B keep the minimum. If the total slope angle of two line is less than 180°, the data point *B* satisfy the compressed condition.

Continuing to examine the slope angle of point *C* which is more than 180°, therefore the data point *C* can't be compressed, it will be regarded as a new start of next piece of data. Finally the least squares will be used to fit the endpoint of each interval and the intersection of each fitting curve is regarded as an inflection which is displayed in Fig.7.

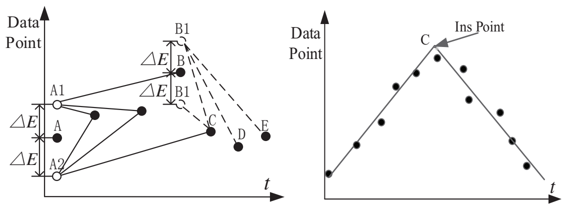

Fig.7. Principle of Swing Door Trend algorithm

The state data such as X-axis speed, axis current, and axis actual position of CNC machine tool, which obtain in the *S* pieces machining process had been handled by Swing Door Trend algorithm. Then recovered by linear interpolation and the least squares fitting via Matlab.

The compressing error are shown in table1. It can conclude that at the same tolerance *ΔE*, using the least squares fitting to recover the compressed data significantly reduced the absolute error *AE* and increased the compression ratio *CR*.

Table 1. The compressing error of two methods.

variables (x-axis)	ΔE	original data	storage data	CR	AE (Line)	AE (LSM)
speed(mm/s)	0.1	18045	8978	2.01	0.2107	0.2107
current(A)	0.5	18045	2855	6.32	0.8351	0.8351
position(mm)	0.05	18045	12276	1.47	0.0967	0.0967

The original data and recovered data of X-axis speed are plotted in Fig.8. SDT-LSM algorithm greatly preserves the characteristic of the original data and removed fluctuations signal, which makes the recovered data more close to the original one. Therefore the compression algorithm is feasible and effective.

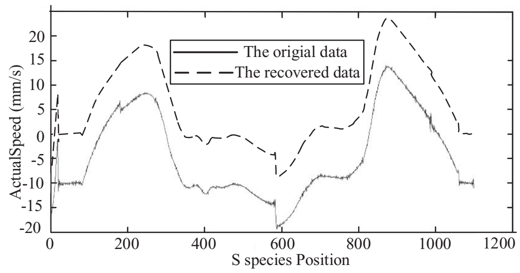

Fig.8. Original data and recovered data about X-axis speed

4. Further application of the state data

The state data adopts C/S module to store and access. The client of OPC acquisition software install on the CNC machine tool, the acquainted data will be stored in a local database via the factory's network. User can monitor the data on web client by accessing the web server. While the CNC machine tool where install OPC acquisition client just keep communicating with nearby machine's computer, so needs to use the oriented-service programming technology to realize the storage and callback of the data between different web clients. This paper used the Web service technology to satisfy the factory demand, the structure of network communication as the follow Fig.9.

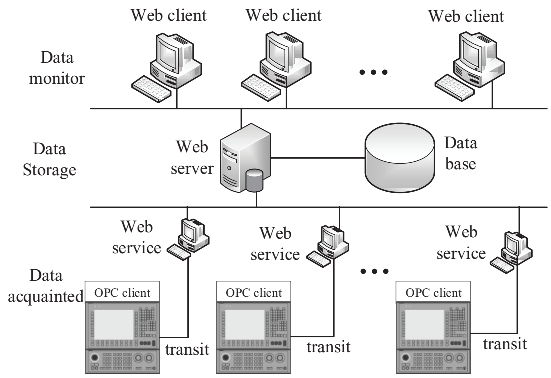

Fig.9. The structure of network communication

The processing data is the direct reflection of the CNC machine tool. The result of data mining such as prediction, singular point analysis, and association rules can be used in fault warning and diagnosis. Particularly, acquainted data could be divided into one dimension or multi dimension time sequence according the fault rules. Time window sliding technique is adopted to establish the machining state model.

Using time sequence similarity analysis and cluster analysis can realize the prediction of the state model. Commonly used measure criteria is similar value ε, the most similarity sequence can be obtained in the massive historical data.

$$corr(X_1, X_2) = \frac{\sum_{i=1}^{n}(x_{1i} - \lambda(x_1))(x_{2i} - \lambda(x_2))}{\sqrt{\sum_{i=1}^{n}(x_{1i} - \lambda(x_1))^2(x_{2i} - \lambda(x_2))^2}} \quad (\varepsilon - similarity) \tag{3}$$

Where x_{1i}, x_{2i} are respectively the target sequence and history sequence. $\lambda(x_1)$, $\lambda(x_2)$ represent the average of each sequence. Then data cluster analysis is adopted to obtain the accurate prediction value. Aim to eliminate the influence of singular point and the noise of sequence, this paper introduced the DENCLUE algorithms which based on density cluster. The Gaussian density influence function of each sequence as follow:

$$f_B^D(x) = f_{Gauss}(x, x_i) = \sum_{i=1}^{n} f_B^{x_i}(x) = f_B^{x_1}(x) + f_B^{x_2}(x) + \cdots + f_B^{x_n}(x) = \sum_{i=1}^{n} e^{-\frac{d(x,xi)^2}{2\delta^2}} \tag{4}$$

Where x_i is the most similarity sequence which obtained in above, $f_{Gauss(x,xi)}$ is the ratio function. Then calculate the maximum density point and the largest density growth direction. Each similar sequences will be distributed into different clusters. If most of the similar sequences belongs to the *A* cluster, the value of cluster centre would be the prediction result of the CNC machine tool's state module. Then the fault warning and diagnosis of the CNC machine tool can be achieved by the prediction result.

5. Conclusions

In this paper, the state data acquisition of CNC machine tools has been realized based on OPC specification, the communication framework of state data, and the application of data mining are introduced. Through this research, user are able to build the remote monitoring platform with a high confidence which achieving unmanned control, fault warning, and assess the health status of CNC machine tool parts. Overall, it is important to promote the intelligent transformation of the traditional industry.

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