

PAPER • OPEN ACCESS

## NC Equipment Fault Diagnosis Research in Uncertain Circumstance Based on Information Fusion and Bayesian Networks Integrated

To cite this article: Tao Zhang *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **493** 012151

View the [article online](#) for updates and enhancements.

# NC Equipment Fault Diagnosis Research in Uncertain Circumstance Based on Information Fusion and Bayesian Networks Integrated

Tao Zhang <sup>1,3</sup>, Weixi Ji <sup>1,2,\*</sup>, Yongtao Qiu <sup>1</sup>

<sup>1</sup>School of Mechanical Engineering, Jiangnan University, WuXi, China

<sup>2</sup>Jiangsu Key Laboratory of Advanced Food Manufacturing Equipment and Technology, Jiangnan University, WuXi, China

<sup>3</sup>Anhui Technical College of Mechanical and Electrical Engineering, Wuhu, China

\*Contact Author E-mail: skgczt@163.com

**Abstract.** With the development of NC Equipment for the direction of high-speed, high power and high reliability, there are lots of complicated and coupling relationship as well as uncertain elements and information between and among the components. Two theory methods that are combined based on information fusion technology and Bayesian network are proposed in this paper. Firstly, more information fusion method can increase the completeness of the fault information to overcome the disadvantages of the single sensor; Secondly, Bayesian network is one of most effective means which not only can decrease the ambiguity of fault information but also improve the speed of fault diagnosis. At last, the experimental study of NC tool-machines is verified to be valid, which strengthens the practical value.

**Keywords:** NC equipment fault diagnosis, Information fusion, Bayesian networks, Energy consumption.

## 1. Introduction

With the development of industrial system, such as high speed, high power, high reliability and the direction of large-scale, there are a lot of component is complex, the relationship of the associated coupling, with uncertain factors and uncertain information. The numerical control equipment, in particular, itself is a complex electromechanical liquid gas intelligent device, when fault occurs, a fault may have a variety of signs, and shows a symptom and often caused by a variety of fault. Therefore, rely on a single theory method and the single source of the fault is difficult to make an accurate diagnosis, which makes fault diagnosis theory is far from meet the requirements of practical application, fault diagnosis theory needs to be further improved.

First collect numerical control equipment common fault information, depending on the fault classification summarizes numerical control equipment of fault symptoms and causes, and then summarizes according to the fault information, by using multi-sensor collection equipment, processing monitoring information from machine, based on the bayesian networks, rough set data processing,



research and development of expert diagnosis system, realize the uncertain environment of intelligent fault diagnosis of NC equipment.

## 2. Analysis of NC Equipment Fault Diagnosis

NC machine tool is a very complex electromechanical integration products, made up of many different modules, different manufacturers of different types of machine tools, its configuration is different also. Respectively to different fault analysis module design, in according to actual needs, different modules combination, became a new machine, but there will be a lot of problems in the process of its implementation.

NC machine tool spindle part is a major components affect the machining accuracy of machine tool, its influence machining precision of work piece rotary precision. The power size and the turning speed affects machining efficiency. Automatic transmission, it must stop and influence the degree of automation of machine tools such as tool change. Therefore, spindle assembly requirements has adapted to the machine working performance of high rotation accuracy, stiffness, vibration resistance, abrasion resistance and low temperature rise. In structure, must be very little to solve the cutting tool and work piece clamping, configuration, and bearing clearance adjustment and lubrication of the bearing seal, etc.

The spindle structure according to the specifications of the NC machine tools, precision using different spindle bearings. In general, small specifications of the spindle assembly of NC machine tool is used more group high precision rolling bearing; Heavy duty NC machine tools using liquid hydrostatic bearing; High precision nc machine tools using aerostatic bearing; Turn velocity 20000 RPM of the spindle speed using magnetic bearings or silicon nitride ceramic ball bearing.

Table 1 and table 2 list the main components of equipment: main shaft transmission chain and fault diagnosis of ball screw pair of reasons.

**Table 1.** Main shaft transmission chain between fault symptoms and failure mode

No.	Fault symptoms	Failure mode
1	Overheating	1. Before and after the main shaft bearing damage or bearing is not clean. 2. Before the main shaft cover and spindle box body gland grind. 3. Bearing lubrication oil run out or grease blotted out too much.
2	Stop when spindle is cutting strongly	1. Motor connected to the spindle. 2. Belt too loose. 3. A little oil on belt. 4. Friction clutch adjustment too loose or wear.
3	Too noisy	1. Lack of lubrication 2. Small pulleys and big belt wheel transmission 3. Main shaft connected to the motor belt too tight 4. Gear backlash uneven or gear damage 5. Drive bearing damage or bending the shaft
4	No oil circulation or insufficient lubrication	1. The turning of oil pump is not correct, or gap is too big. 2. Suction tubing not inserted below the oil level in the tank 3. Tubing or filter clogging Insufficient pressure lubricating oil.
5	Lubricating oil leak	1. Lubricating oil quantity too much. 2. Check if all seals was damaged. 3. Pipe damage.
6	Cutting tool can't clamp	1. Spring displacement is too small. 2. The cutter holder knife on the spring nut is too loose.
7	Cutting tool can't loosen after clamping	1. Spring pressing nipped is too tight. 2. The hydraulic cylinder pressure and stroke is not enough.

**Table 2.** Main shaft transmission chain between fault symptoms and failure mode

No.	Fault symptoms	Failure mode
1	Too noisy	1.Screw bearing gland pressing situation is not good. 2.Be damaged. 3.Coupling is loose between motor and screw 4.Bad lubrication.
2	Ball screw motion is not flexible	1.The axial preload load is too big. 2. Lead screw and guide rail is not parallel. 3.Nut axis is not parallel with guide rail.
3	Bad lubrication	Check the ball screw pair of lubrication
4	Guide grind	1.Poor guide material. 2. Research quality does not meet the requirements.
5	Unable to move on guide motion moving parts	1.Guideway grind. 2. Guide plate grind. 3.Guide fillet and guide gap is too small.

### 3. Multiple information fusion fault diagnosis bayesian

#### 3.1. Bayesian Net

Bayesian network is also known as belief network is a directed acyclic graph based on the structure of the network probability model, the use of conditional probability said its quantitative relations, use of a binary group B (G, P) said a bayesian network, including: G the directed acyclic graph;P said conditional probability tables.([5][6])

Based on the basic principle of bayesian networks, will work with the component fault diagnosis information, such as the fault symptoms and fault modes, etc.) in the form of a node, the relationship between nodes in network are connected to the edge, close degree is using the conditional probability between nodes.Bayesian network was applied to fault diagnosis of machine tool parts, not only can effectively deal with uncertainty in the process of fault diagnosis problem, also can effectively express and the fusion of multi-source heterogeneous information.

#### 3.2. Bayesian net of fault diagnosis

Mainly to absorb NC equipment fault diagnosis technology and its application in other fields of technology as the foundation, in view of the specific equipment, combined with the fault mechanism, prior knowledge is used to establish the corresponding fault diagnosis knowledge base and inference rules library.Using modern information processing technology, to extract signal pattern recognition or classification of equipment, the system fault diagnosis, the cause of the problem analysis, fault location and fault forecasting, etc.In on the system status information acquisition pretreatment technology, mainly is absorbed and some applications in other fields.

Through to the information of fault information processing, and construct the integrated fault diagnosis based on information fusion framework, as shown in figure 1, the fault diagnosis process is divided into three layers, namely the data layer, characteristic layer based on information fusion and decision-makers.Among them, the data layer is the analysis of much information processing, the system of state fusion estimation and parameters, the characteristic parameters of extracting diagnosis required, the data layer integration can be or data to the data to the data fusion feature fusion;Characteristics of layer is by using signal processing technology is analyzed, the results of data layer integration of feature extraction, and other related characteristic information fusion processing to obtain the required identification characteristics, effective decision-making for failure;Policy makers use intelligent diagnosis technology for different kinds of diagnostic object, combining the characteristics of neural network nonlinear nature, have strong ability of learning and fault tolerance, combined with fuzzy technology mainly solve those from the process itself, uncertainty and inaccuracy of difficult, fuzzy neural network fusion reasoning analysis, the final diagnosis conclusion.It is listed in Fig. 1.

#### 4. Conclusion

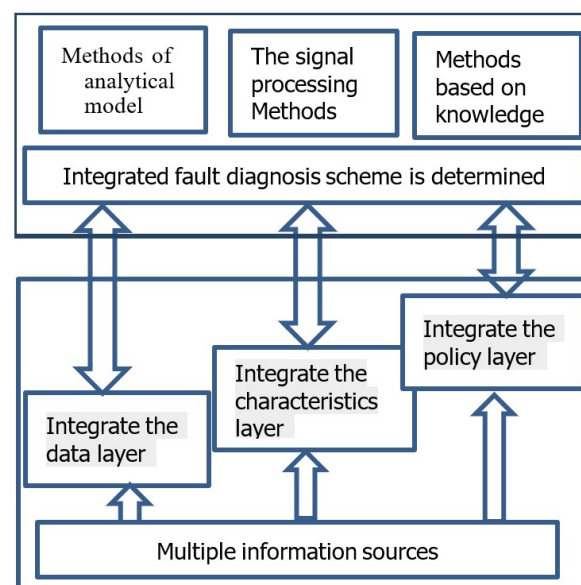
Bayesian network as a new way of dealing with uncertainty knowledge, has a solid basis of probability theory, and is able to express the knowledge structure, but is applied to fault diagnosis of nc equipment under the uncertain conditions of research remains to be strengthened, the advantage of bayesian network used in fault diagnosis are as follows:

(1) The bayesian network has a solid theoretical basis. Bayesian network based on the probabilistic inference, thrust convincing results. And compared with bayesian method, the bayesian network to the requirements of the prior probability is greatly reduced. At the same time, the bayesian network expression condition of independent performance clear correlation between the said equipment failure.

(2) Probabilistic inference algorithm of bayesian networks have a mature and develop software. Bayesian network inference is to use the expression of conditional independence, according to the existing information to value and probability calculation process. When the bayesian network expression of equipment fault diagnosis problem, is to use some of the fault symptom fast calculation of failure probability information process, when other node variable probability information.

(3) The bayesian network is more suitable for equipment fault diagnosis problem. Bayesian network accumulation can at any time to learn through practice to improve the network structure and parameters, improve the ability of fault diagnosis. Bayesian network to accept the new information will update immediately after the probability information in the network, is suitable for express more complicated and uncertainty problems.

(4) The bayesian network has a strong ability to learn. Has the learning ability is an important characteristic of artificial intelligence, bayesian network learning is to use a given set of training samples to look for a best matching network process, usually in the fault diagnosis in the field of applications, the random variables are given by the domain experts of cause and effect diagram, get the bayesian network structure, therefore, in the field of fault diagnosis through learning sample set of conditional probability table more meaningful.



**Fig. 1** Multiple information fusion integrated fault diagnosis scheme

#### Acknowledgements

This research was financially supported by the Quality Engineering Project (Grant No. 2015sxxz064. 2016jxtd027) Innovation and Development Plan of Action (Grant No. XM-01). And Excellent young talents of colleges and universities support plan (Grant No. gxyqZD2016480) in A Hui province department of education.

**References**

- [1] Ji Peng, Zhang Chenghui, Ning Yong. New fuzzy weighting clustering algorithm based on the fuzzy c-means algorithm. Binary Information Press, 2008, 4(4):1447-1452
- [2] Li Pingkang, Wang Xun, Wang Quanmin, Jin Taotao. Approach to using MSPC for power plant process monitoring and fault diagnosis. Chemical Industry Press, 2008, 59(7):1790-1796
- [3] Wang Guimei, Wang Qingdong, Li Jiangbo, Wei Jianfeng. Mine elevator comprehensive performance testing system based on virtual instrument. ICIEA 2008, 3rd IEEE Conference on Industrial Electronics and Applications, Singapore, Singapore, 2008:1027-1030
- [4] Chen Xiaojing, Wu Di, He Yong, et al. An effective signal de-noising algorithm combining optimal wavelet packet basis and translation-invariant algorithm. 1st International Congress on Image and Signal Processing, Sanya, Hainan, China, 2008:275-279
- [5] Liu Siyuan, Jiang Wanlu, Wu Shengqiang. Fault diagnosis of characteristics fusion based on rough set and principal component analysis in hydraulic pump. 7th International Conference on Fluid Power Transmission and Control(ICFP 2009), 2009, Hangzhou, zhejiang, China, 07-10 Apr. 2009:860-864
- [6] Huifeng Niu, Wanlu Jiang, Siyuan Liu. Research on the Hybrid Fault Diagnosis Approach Based on Artificial Immune Algorithm. Proceedings of 4th International Conference on Natural Computation (ICNC'2008), 2008, Vol.6, Jinan, Shandong, China, 18-20 Oct. 2008:667-670