NEW METHODS FOR DIAGNOSTIC OF CNC MACHINE TOOLS

Ing. Zajačko I., PhD., prof. Dr. Ing. Kuric I., Ing. Císar M., PhD.

Department of Automation and Production Systems, Faculty of Mechanical Engineering

University of Zilina, Slovak Republic

ivan.zajacko@fstroj.uniza.sk

Abstract:

Diagnostic system is very important part of a system for fault prediction and it is very helpful tool to improve efficiency of industry production. If we want to attain an optimalisation of production, have shortest lead times, low costs of production we need accurate information from maximal number of criteria collected from production machines, to setup best process parameters focused on reaching acceptable life time of machine parts.

For this reason, we need improve the power of diagnostic systems with implementation of new methods with new possibilities.

Keywords: MULTICRITERIAL DIAGNOSTIC, ELECTRIC CONSUMPTION, VIBRATION DIAGNOSTIC, DATA MINING

1. Introduction

Today's trend in factories is to obtain a maximal automation, which corresponds to the ideas of the Idea Industry 4.0 concept. Machines are connected to a collaborative community and people cooperate with machines robots cooperate according to collaborative principles and production is set up to a point with zero faults and zero wasted time. For efficient and precise production management, we need to implement tools and methods to eliminate unpredictable failures and errors that reduce the production performance and cause financial losses. One way is to implement a powerful multi-criteria diagnostic systems that enables us to monitor real-time production facilities while allowing us to analyze collected data online for the diagnostics of manufacturing processes. Multi-criteria diagnostics is very beneficial, based on analysis of the results obtained from manufacturers, exact information about weaknesses in the processes of production and proposed solutions to existing or predictable problems can be made. Usage of modern technologies is needed to gather large amounts of data from multicriterial diagnostic processes. Accurate use of the data, often stored in large databases is used to understand production processes, to achieve optimization of production processes or maintenance, to reduce the cost of maintenance and at the same time to maximize the effectivity of production processes. This is particularly visible in the Industry 4.0 concept. This concept assumes the use of various modern information technologies, such as the Cyber-Physical Systems (CBS) or Internet of Things (IoT) – processing the Big Data. The main idea here is the preparation of a computerized manufacturing environment, which will simply allow us to increase flexibility and efficiency of production through integration of various activities and effective communication between a client and a producer - Customer to Business (C2B), as well as between a producer and a supplier Business to Business (B2B).

In respect of the above, methods of acquisition, gathering, processing and, most of all, exploration and analysis of data become particularly important. It seems that predictions of experts have become true – at the beginning of this millennium they stated that data analysis would be a revolutionary achievement of the following or coming decade.

The reason for the creation of specialized nodes is to ensure the maximum possible level of production quality and optimization of logistic processes. However, this causes a new challenge in the production process, the formation of hierarchical dependence of the manufacturing processes where consecutive stages of production within the company are dependent on the production of the previous stages in the life cycle of production. For this reason, the occurrence of random and sudden interruptions of production or unplanned production decline is undesirable phenomenon with potentially serious consequences for the entire production. Prediction of the problems determined by the analysis of information obtained in production by obtaining measurable data is very beneficial method of eliminating the problems of manufacturing. Production processes are complex in nature with a large number of interacting actors. Results of mono-criteria diagnostics are useful only in analyzing an isolated property of the production process, or in the case of mono-criteria diagnostics of more complex property (e.g. vibrations) the result have broader scope, but are susceptible to errors due to misinterpretation of the analyzed results or the emergence of errors in cases where the process is affected by new actor that did not appeared previously and then "hiddenly" influence the result.

Our aim is to as much as possible get an accurate and comprehensive view of the manufacturing process and obtain measurement results that allow us by their analysis to produce results with high diagnostic value with accurate description of the state of the manufacturing process. Data obtained through multi-criteria diagnosis have a very large content value. Depending on the way in which we look at the data, in way of their further processing and, depending on the interpretation of the results obtained by the analysis of the collected data we can not only predict failures and need of scheduled maintenance, and predict other phenomenons related to the production and manufacturing process. With correct data analysis and correct interpretation of data we can create very precise results for optimization of energy requirements and environmental impacts of manufacturing processes, also we can optimize usage of human resources, and material flow, and other important factors. Because of wide application opportunities of the proposed multi-criteria diagnostics, and analysis of the results obtained by it we can apply the research results in a manufacturing companies.

Aim of our research is to ensure the development of analytical tools that process the data obtained through multi-criteria diagnostics to obtain the required answers to specific questions defined by mechanical engineering companies in the topic of increasing efficiency and optimizing production processes. The resulting data set has a very large scope and the maximization of the content value is however dependent on a thorough knowledge of its structure and in particular in accordance with the dependencies observed in gathered data. Production process is a continuous sequence of tasks and the various actions in the production process are not an isolated factors affecting the final product, but are an integral set of mutually interacting factors that have both a direct impact on final product manufacturing, and also often lead to mutual interaction between each parameter by means of a visible but also hidden dependencies that need to be understood before of the processing and interpretation of data obtained thru multi-criteria diagnostics.

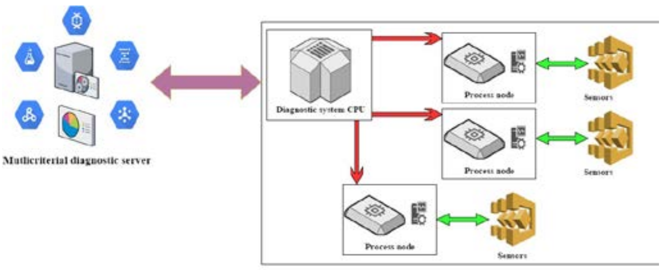
2. Design of multicriterial diagnostic system

In order to achieve maximum accuracy of diagnostic of the production machines, we have designed a conceptual design of the hardware of the diagnostic system. The proposed hardware is based on the paradigm of autonomy of the diagnostic system in production: "The functionality of the proposed diagnostic system must be independent from the control system of the diagnosed device."

The necessary conditions for achieving the proposed system is:

• it must work with its own and independent control system
• it must autonomously collect the data and process them to the required representation without the need for any interaction with the control system of the diagnostic system
• it must have a separate data transfer channel to the parent system (server)
• it must have separate power supply

To meet the defined conditions, we designed the following architecture of the diagnostic system:



Multicriterial Diagnostic System

Because of the need to process and transmit large amounts of data in a short period of time, the internal communication bus between the process nodes and the central processor unit must have high bandwidth. Due to the possible requirement of placing the entire diagnostic system to proximity of the diagnosed device interference may occur on the communication bus between processing nodes and central unit, because of that hardened communication bus must be used, and likewise the communication protocol must use checksums and have autocorrecting capabilities.

Process nodes must be connected to individual sensors via lines that can transmit measured data without restricting the production and without loss of transfer speed. The types of lines depend exclusively on a communication pair, that consists of a suitable sensor for measurement and a process node with sufficient power.

Process nodes can be differentiated by several logical criteria mainly the following:

• position of sensors on the production device
• process node performance (defined by volume and type of data collected by sensors)
• the number of sensors connected
• type of connected sensors

The main reason for creating process nodes is to take advantage of the decentralization of the diagnostic system. Decentralization enables us to create topologically large applications, greatly simplifies the cabling structure, reduces aggregate transmission speeds and, in the event of a failure of certain node it allows to continuously monitor all parameters of non-affected nodes.
At the same time, we also enable us to decentralize the necessary computational power to process the acquired data from the sensors through their pre-processing functions on process nodes and then send them in the optimized range and shape to the central processing unit.

The subsystem of sensors designed for the diagnostic system is dependent on specific implementations. The main factor determining their choice is their suitability for the chosen purpose, especially in terms of ranges and speed of data collection. At the same time, sensors must be selected based on the suitability of their application for the particular conditions of the monitored device and the environment in which they will be installed. A prerequisite for choice of sensors is connectivity in digital format or must be able to connect via analog-to-digital converter to a digital format.

3. Processing of collected data

With multi-criteria diagnostics of the production process we are collecting in a relatively short time an extensive set of data. We need very powerful analytical methods and tools to obtain applicable results in real time. Therefore, we will focus our research on the implementation of advanced analytical methods for processing the large data set on powerful computing devices.

The process of obtaining the necessary performance of the diagnostic system is by processing of the data obtained by means of progressive tools designed for the processing of large volumes of data. We consider Big Data Tools or Modified Business Intelligence Tools. Modification of Business Intelligence tools is required primarily because of their primary focus on historical data processing. When BI is applied to the Multi Criteria Diagnostics System, the implementation change is required to process current data.

In our research, we focus on analyzing the data obtained in order to create a system of predictive care for the device - i.e., to predict the occurrence of a potential malfunction with the purpose of timely elimination of the malfunction and thus to prevent the device from failing.

From these approaches, we are focusing on Data mining and Knowledge data discovery. Through these methods, we perform analysis of the data obtained in order to identify correlations between the measured data and evaluate the actual condition of the monitored device by processing the acquired data through modified methods of conventional diagnostic methods.

From the point of view of the user, application of specific Data Mining methods for extraction of knowledge hidden in data is the least laborconsuming stage, in comparison with the often cumbersome and technically complicated preceding stages, related to understanding of a problem, proper data preparation, filtering and converting data with regard to a given task. In the knowledge extraction process the data exploration results can be obtained automatically. However, the preceding and the final stages (the latter focused on the analysis of obtained results) require the user to be familiar with problems of mathematics, statistics, as well as to have specialized knowledge regarding the diagnostic branch.

Knowledge data discovery is used to discover new knowledge in stored datas. Data analysis is started by identification of the research problem, while further exploration is conducted on a data sample obtained from a larger data set. Then, relations between data are mostly looked for using data visualization tools and the data set is prepared for modeling. The last stage is the evaluation of obtained results and attempt at their translation into real conditions of company functioning.

Success implementation of data mining is connected with full and correct phases of implementation. The most frequently distinguished tasks are:

• Description.
• Classification.
• Regression.
• Clustering.
• Looking for associations.

Description consists in concise summarizing of analyzed data. During realization of this task, graphs are frequently used alongside one-dimensional or multidimensional tables or rules for data description.

Classification belongs to the so-called supervised ("learning with teacher") group and is aimed at creating a dependency model between independent variables describing given objects or phenomenon and a dependent variable in an attribute form. It is done on the basis of the so-called teaching set, containing a set of objects with known values of independentand dependent variables. The purpose is to apply this model for assigning new cases to a selected class of the dependent variable. The most frequently used methods in this area are classification trees, neural networks, support vector machines, the naive Bayesian classifier or Bayesian networks.

Regression also belongs to the supervised group and plays a similar role to classification, but in the dependency model created on the basis of the teaching set, the dependent variable is in a numerical form. Examples of methods used to realize the regression task are neural networks, simple and multiple regression, and regression trees.

Clustering does not use a teacher (there is no dependent variable here) and consists in creating clusters (groups) of objects in a way to ensure the highest possible similarity between objects in one cluster, as regards values of the considered independent variables, with simultaneously maintained maximal possible differences between particular clusters. In this area, two groups of methods are applied: hierarchical ones, building the so-called dendrograms, and non-hierarchical ones, creating entirely separate clusters.

Looking for associations consists in finding dependencies in an analyzed data set. These dependencies do not have a functional character; rather, they are based on coexistence of values of particular variables.

4. Model application example

Our system of multi-criteria diagnostics was applied on the diagnosis of the turning process.

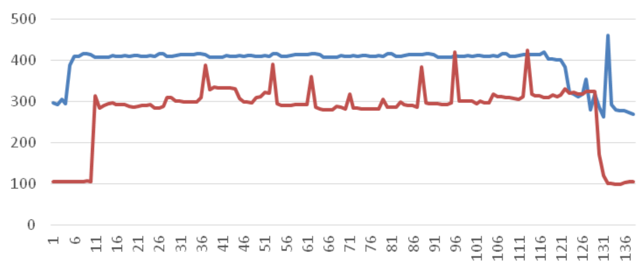
We have tracked:

- Vibration
- Temperature
- Power Consumption parameters

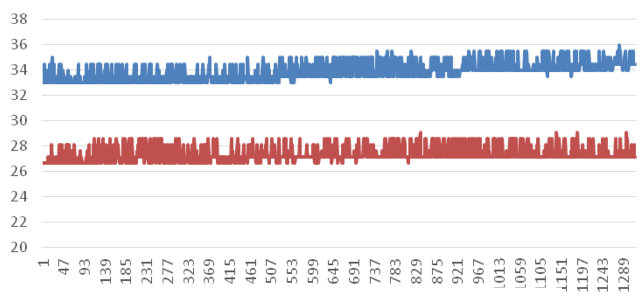
We have fully utilized the described philosophy of the decentralized hardware of the diagnostic system. We have saved and pre-processed data stored in a database created through Microsoft SQL Server.

We performed several repetitive measurements on the device while working without a fault, and then we introduced a model of error that is common in the production process.

The effect of the error in the production process is evident from the following graphs:



Performance comparison

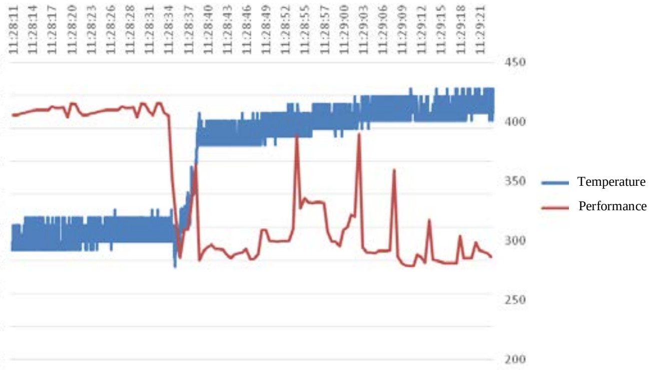


Temperature comparison

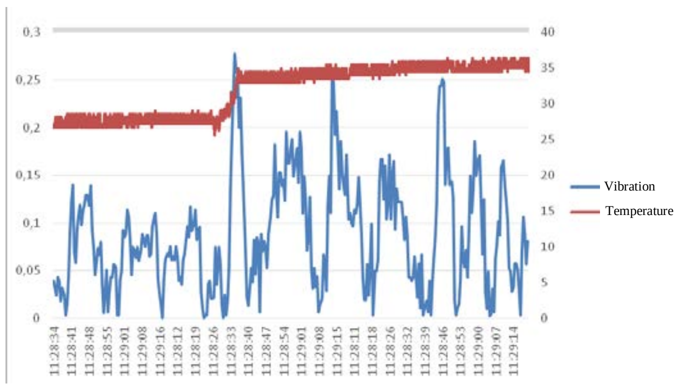
Next graph show Vibration comparison

Vibration comparison

The next step was to apply data mining to the obtained data. After applying individual methods of data mining, we found a correlation between the individual parameters of the production process. For clarity, we chose to visualize pairs correlations with graphs.



Dependence Temperatures and Performance



Dependence Vibration and Temperatures

4. Conclusion

By applying multi-criteria diagnostics to the well-known processes of lathe manufacturing operations, we expected to find hidden relationships between the machine state and the measured parameters, and we also expected to find new connections between the production parameters.

Our assumptions have been fulfilled. The correlations between the monitored characteristics of the production processes have been shown as expected, thus confirming the accuracy of the proposed hardware and methods of processing the obtained data.

In further research, we will continue to look at increasing the implementation capabilities of multi-criteria diagnostics systems and expanding the precise knowledge base and understanding of the processes under examination.

5. References

1. Provost F. Data Science for Business, O'Reilly Media Inc., 2013, (Provost F., T. Fawcett)

2. Witten I. Data Mining, Morgan Kaufman Publishers, 2011, (Witten I., F. Eibe, M. Hall)

3. Cheng. K. Machining Dynamics, Springer, 2009

4. Pandilov Z., Milecki A., Nowak A., Gorski F., Grajewski D., Ciglar D., Mulc T., Klaić M., Virtual Modelling And Simulation Of A CNC Machine Feed Drive System, Trans. of FAMENA, 39, 4, 37–54, 2016.

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