System for Monitoring and Optimization of Micro- and Nano-Machining Processes Using Intelligent Voice and Visual Communication

Dariusz Lipinski and Maciej Majewski

Koszalin University of Technology, Department of Mechanical Engineering
Raclawicka 15-17, 75-620 Koszalin, Poland
{dariusz.lipinski,maciej.majewski}@tu.koszalin.pl
http://kmp.wm.tu.koszalin.pl

Abstract. The article describes a new concept of voice and visual communication between the human operator and a system for monitoring and optimization of processes of micro- and nano-machining. The remote system for monitoring and optimization of process quality, which is equipped with a speech interface and artificial intelligence, is presented in exemplary application in the precision grinding process. The developed concept proposes an architecture of the system equipped with a data analysis layer, process supervision layer, decision layer, communication subsystem by speech and natural language, and visual communication subsystem using voice descriptions. In the proposed system, computational intelligence methods allow for real-time data analysis of monitored processes, configuration of the system, process supervision and optimization based on the process features and quality models. The concept allows for the development of universal and elastic systems which are independent of a type of manufacturing process, machining parameters and conditions. The developed block structure of the system allows for applications in monitoring of many other processes of micro- and nano-machining.

Keywords: monitoring and optimization, micro- and nano-machining processes, intelligent system, intelligent interface, process quality, measurement data analysis, modern machining process, artificial intelligence.

1 Introduction

Processes of micro- and nano-machining in the industry of today can be performed using a hybrid system for monitoring, optimization and forecasting of machining process quality, equipped with a layer of distance voice and visual communication between the system and human operators. The system of monitoring and optimization of the quality of the processes of micro- and nano-machining, presented in exemplary application in the precision grinding processes, features the possibility for many other applications, future development and experiments. Its main tasks include: modeling of the process, assessment of inaccuracy effects, identification of inaccuracy causes, optimization of the process conditions and parameters.

H. Yin et al. (Eds.): IDEAL 2013, LNCS 8206, pp. 16–23, 2013.

The scientific aim of the research is to develop complex fundamentals of building new systems (fig. 1) for monitoring and optimization of micro- and nano-machining processes using intelligent voice and visual communication. The

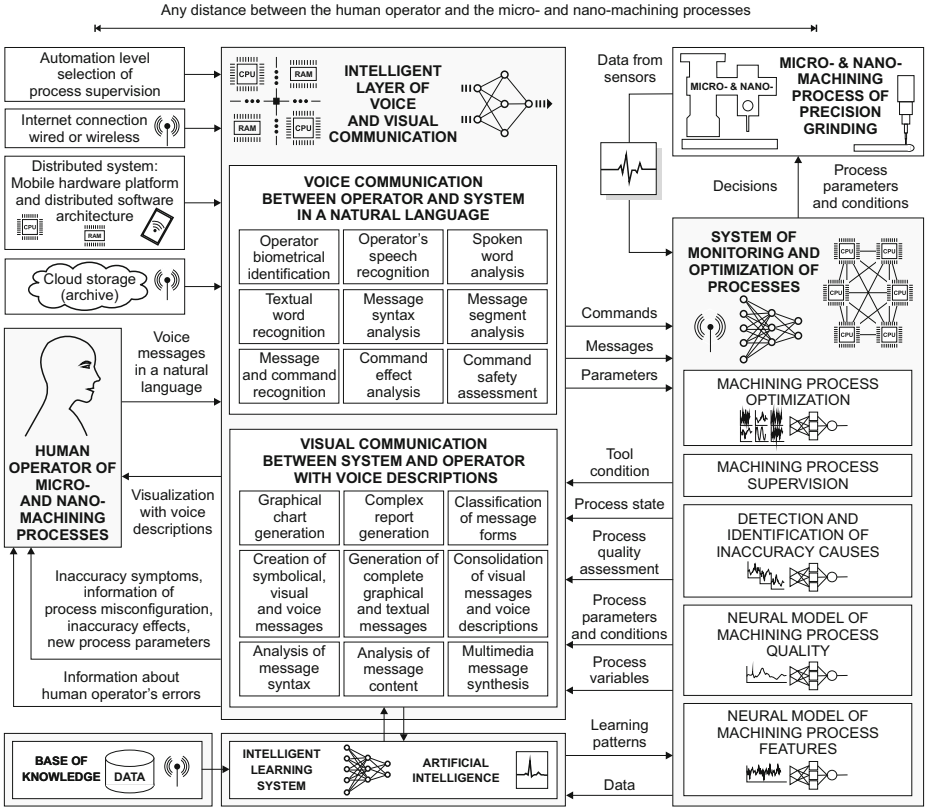

Fig. 1. Concept of voice and visual communication between the operator and a system for monitoring and optimization of micro- and nano-machining processes.

design and implementation of intelligent systems for monitoring and optimization of manufacturing processes is an important field of research. In these systems, a natural language interface using speech is ideal because it is the most natural, flexible, efficient, and economical form of human communication. This concept proposes a novel approach to intelligent systems for monitoring and optimization of the processes of micro- and nano-machining using intelligent voice and visual communication, with particular emphasis on their ability to be truly flexible, adaptive, human error-tolerant, and supportive both of human operators and intelligent agents in distributed systems architectures.

Application of intelligent interactive systems for monitoring and optimization of machining processes using a natural language offers many advantages.

It ensures robustness against human operator errors and efficient supervision of manufacturing processes with adjustable level of automated supervision. Natural language interfaces also improve the cooperation between a human operator and a system in respect to the richness of communication. Further, intelligent interaction allows for higher organization level of manufacturing processes, which is significant for their efficiency and humanization. Decision and optimization systems can be remote elements of manufacturing processes.

The design of the proposed system can be considered as an attempt to create a standard intelligent system for monitoring and optimization of machining processes using natural language communication. It is very significant for the development of new effective and flexible manufacturing methods. It can also contribute for increase of efficiency and decrease of costs of the production processes. This system provides an innovative solution allowing for more complete advantages of modern manufacturing processes nowadays.

2 The State of the Art

There is a need for remote systems of monitoring and optimization of machining processes in reconfigurable manufacturing systems to reduce bottlenecks that occur in associated tasks to be performed by these systems using technological devices. The tasks include: modeling of the process features and quality, assessment of inaccuracy effects, identification of inaccuracy causes, optimization of the process conditions and parameters. These bottlenecks can occur as a result of the mass production of custom products.

The sustainability of existing manufacturing resources and enhancement of the machining efficiency is an important field of applied research. The current research and recent advances in development of prototypes of systems for monitoring and optimization of machining processes are described in articles [1,2,3,4]. Those systems consist of computational algorithms for sensor base monitoring and control, and simulations of virtual machining processes. Those systems have been accepted for real-time decision making, sustainable development and efficient use of machining resources.

In many potential applications of these monitoring and optimization systems, the limiting factor may be an ability of the system to model the process features and quality, process the inaccuracy symptoms, solve the misconfiguration issues, compensate the inaccuracy effects, determine the process conditions and parameters. The integration of these systems and remote communication in applications faces a challenge of accuracy, robustness and portability. The integration also gives rise to some new challenges which include integration strategies, coordination of the components with system outputs, and adaptation towards reconfigurable manufacturing systems.

This article offers an approach by using the developed concept of the system of monitoring and optimization of the processes of micro- and nano-machining to deal with the above problems. Selected research article [5] presents innovative solutions in supervision of precise grinding processes and development of a hybrid

system for monitoring, optimization and forecasting of machining process quality. Articles [6,7,8,9,10,11] describe the developed solutions in the range of intelligent voice communication between human operators and technical devices.

3 Description of the System

The proposed system of monitoring and optimization of the processes of micro- and nano-machining, presented in exemplary application in the precision grinding processes, features the universality of application of the developed intelligent algorithms and possibility of application in many other processes of micro- and nano-machining in manufacturing. The developed block structure of the system allows for the development of universal and elastic systems which are independent of a type of manufacturing process, machining parameters and conditions.

The developed concept proposes an architecture of the system (fig. 2) equipped with a data analysis layer, process supervision layer, decision layer, communication subsystem by speech and natural language, and visual communication subsystem using voice descriptions.

The novelty of the system consists of inclusion of adaptive intelligent layers for data analysis, supervision and decision. The system is also capable of analysis of the supervised machining process, configuration of the supervision system, neural modeling of process features, neural modeling of process quality, detection of the inaccuracies, estimation of the inaccuracies results, compensation of the inaccuracies results, and selection of the machining parameters and conditions. In addition it makes an assessment of the correctness of the operator's decisions. The system also consists of mechanisms for meaning analyses of operator's messages and commands given by voice in a natural language, and various visual communication forms with the operator using voice descriptions.

The interaction between the operator and the system by speech and natural language contains intelligent mechanisms for operator biometric identification, speech recognition, word recognition, recognition of messages and commands, syntax analysis of messages, and safety assessment of commands. The interaction between the system and the operator using visual messages with voice descriptions includes intelligent mechanisms for generation of graphical and textual reports, classification of message forms, generation of messages in the graphical and textual forms, consolidation and analysis of message contents, synthesis of multimedia messages.

In the system, the data output layer provides the data and information about the machining parameters and conditions, tool condition, process state, process quality, and process variables. The data input layer contains commands for system control, commands for process monitoring and optimization, commands for process supervision, messages for configuration and interaction with the system of monitoring and optimization.

The structure of the system for monitoring and optimization of micro- and nano-machining processes is presented in abbreviated form on Fig. 3. The numbers in the cycle represent the successive phases of information processing. The

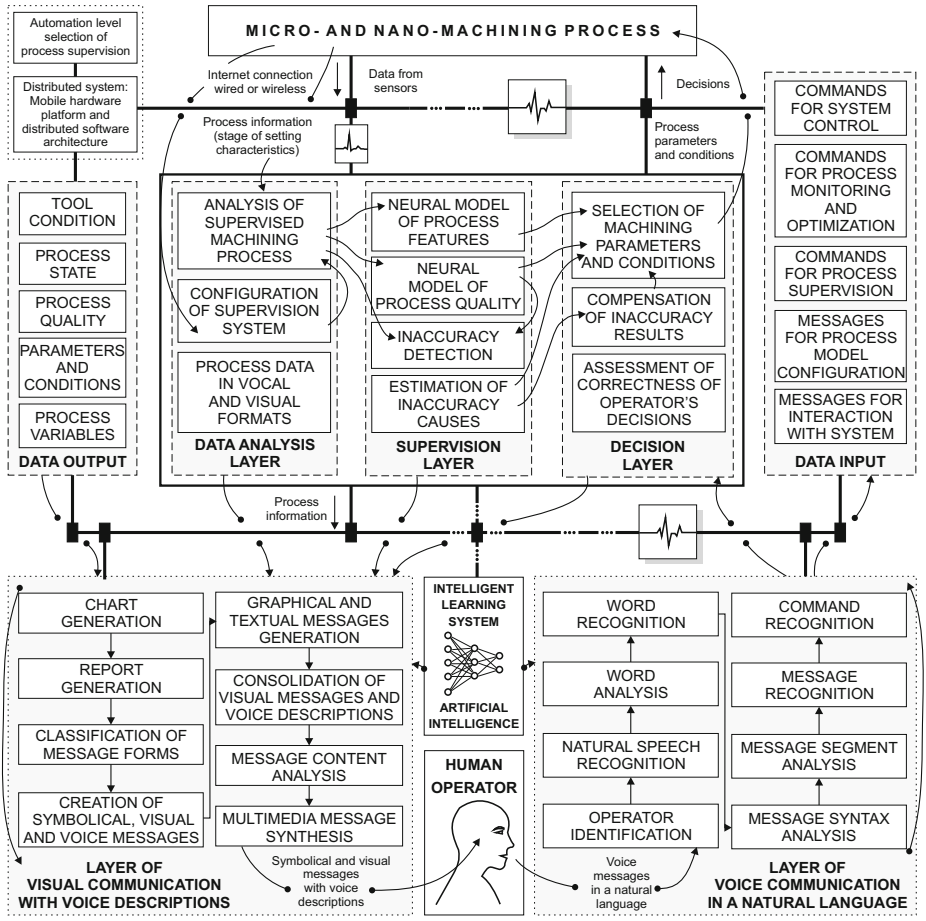

Fig. 2. Concept of a system of distance monitoring and optimization of micro- and nano-machining processes using voice and visual communication

system performs biometric identification of the human operator whose spoken messages in a natural language are converted to text and numerical values. The recognized text is processed by the meaning analysis subsystem using artificial intelligence methods. The processing involves meaning analysis of words, messages and commands in a natural language. The results are recognized meaningful messages and commands, which are sent to the subsystem of data analysis.

The results after the analysis of the supervised process and configuration of the process supervision are further processed with the subsystem of supervision of micro- and nano-machining processes, which is composed of several specialized modules. The subsystem contains modules for modeling of the process features, modeling of the process quality, optimization of the process, determination of allowable changes of the process features, assessment of the grade of changes of the features, detection of inaccuracy causes, identification of inaccuracy causes,

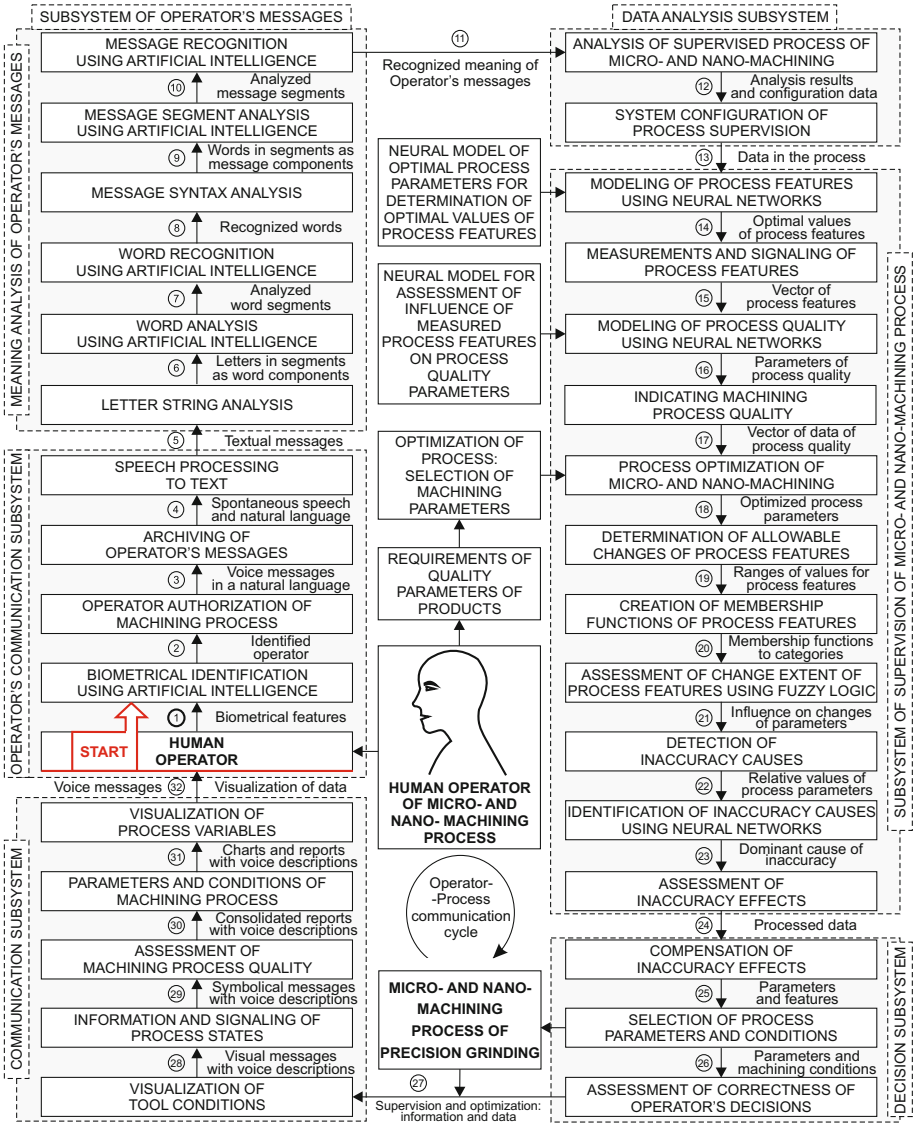

Fig. 3. Structure of a system of distance monitoring and optimization of the machining process using voice and visual communication between the operator and the system

and assessment of inaccuracy effects. The results are subsequently sent to the decision subsystem for compensation of inaccuracy effects, selection of the process parameters and conditions, assessment of correctness of the operator's decisions. The next phase is processing in the subsystem of communication for visualization of the tool condition, signaling of the process states, reporting the assessment results of the machining process quality, reporting the parameters and conditions of the process, visualizations of the variables.

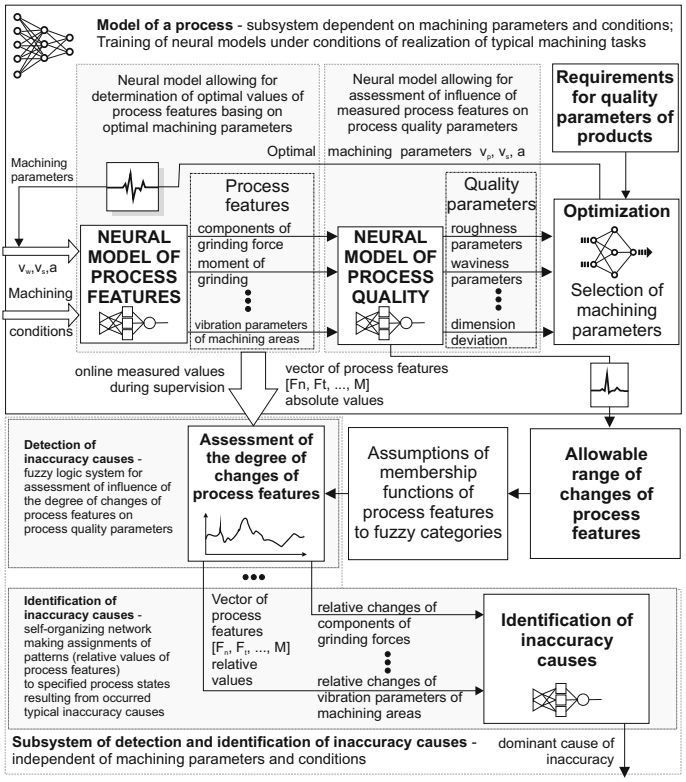

Fig. 4. System for detection of inaccuracies and optimization of machining parameters

The system is equipped with the neural model of the optimal process parameters for determination of optimal values of the process features and the neural model for assessment of influence of the measured process features on the process quality parameters. The models are used in a system (fig. 4) for detection of inaccuracies and optimization of machining parameters.

4 Conclusions and Perspectives

The proposed concept of the system for monitoring and optimization of processes of micro- and nano-machining, equipped with a speech interface and artificial intelligence, allows for the development of universal and elastic systems which are independent of a type of manufacturing process, machining parameters and conditions. The developed block structure of the system allow for application in monitoring of many other processes of micro- and nano-machining. The condition of effectiveness of the system is to equipped it with intelligent mechanisms for modeling of the process features and quality, assessment of inaccuracy effects, identification of inaccuracy causes, optimization of the process conditions and parameters. The experimental results of the proposed system show its promising

performance. The concept can be used for further development and experiments. The system is both effective and flexible which makes its applications possible. As an interface, it allows for more robustness to human's errors. The proposed complex solution also eliminates scarcities of the typical co-operation between human operators and technological devices.

Acknowledgements. The authors would like to thank The National Science Center in Poland (NCN) who provided financial support for this work.

References

1. Abellan-Nebot, J.V., Subiron, R.F.: A Review of Machining Monitoring Systems Based on Artificial Intelligence Process Models. International Journal of Advanced Manufacturing Technology 47, 237–257 (2010)
2. Brown, J.A.: Modern Manufacturing Processes. Industrial Press, New York (2011)
3. Teti, R., Jemielniak, K., O'Donnell, G., Dornfeld, D.: Advanced Monitoring of Machining Operations. CIRP Annals - Manufacturing Technology 59, 717–739 (2010)
4. Groover, M.P.: Fundamentals of Modern Manufacturing. Wiley & Sons, Inc. (2007)
5. Lipiński, D., Kacalak, W.: Assessment of the Accuracy of the Process of Ceramics Grinding with the Use of Fuzzy Interference. In: Beliczynski, B., Dzielinski, A., Iwanowski, M., Ribeiro, B. (eds.) ICANNGA 2007. LNCS, vol. 4431, pp. 596–603. Springer, Heidelberg (2007)
6. Kacalak, W., Majewski, M.: New Intelligent Interactive Automated Systems for Design of Machine Elements and Assemblies. In: Huang, T., Zeng, Z., Li, C., Leung, C.S. (eds.) ICONIP 2012, Part IV. LNCS, vol. 7666, pp. 115–122. Springer, Heidelberg (2012)
7. Kacalak, W., Majewski, M.: Effective Handwriting Recognition System Using Geometrical Character Analysis Algorithms. In: Huang, T., Zeng, Z., Li, C., Leung, C.S. (eds.) ICONIP 2012, Part IV. LNCS, vol. 7666, pp. 248–255. Springer, Heidelberg (2012)
8. Kacalak, W., Majewski, M.: Natural Language Human-Robot Interface Using Evolvable Fuzzy Neural Networks for Mobile Technology. In: Huang, D.-S., Jo, K.-H., Lee, H.-H., Kang, H.-J., Bevilacqua, V. (eds.) ICIC 2009. LNCS, vol. 5754, pp. 480–489. Springer, Heidelberg (2009)
9. Majewski, M., Zurada, J.M.: Sentence Recognition Using Artificial Neural Networks. Knowledge-Based Systems 21(7), 629–635 (2008)
10. Majewski, M., Kacalak, W.: Intelligent System for Natural Language Processing. In: Huang, D.-S., Li, K., Irwin, G.W. (eds.) ICIC 2006. LNCS (LNAI), vol. 4114, pp. 742–747. Springer, Heidelberg (2006)
11. Stuart, K.D., Majewski, M., Trelis, A.B.: Intelligent Semantic-Based System for Corpus Analysis through Hybrid Probabilistic Neural Networks. In: Liu, D., Zhang, H., Polycarpou, M., Alippi, C., He, H. (eds.) ISNN 2011, Part I. LNCS, vol. 6675, pp. 83–92. Springer, Heidelberg (2011)