Intelligent Monitoring and Optimization of Micro- and Nano-Machining Processes

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Abstract. The article describes an innovative concept of intelligent systems for monitoring and optimization of micro- and nano-machining processes, which are equipped with a speech interface and artificial intelligence. The developed concept proposes an architecture of the systems 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 implemented 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 modern concept allows for the development of universal and intelligent systems which are independent of a type of manufacturing process, machining parameters and conditions.

Keywords: process monitoring, process optimization, micro- and nano-machining, intelligent system, modern machining process.

1 Introduction

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

The scientific aim of the research is to develop fundamentals of building interactive systems (Fig. 1) for monitoring and optimization of micro- and nano-machining processes. The design and implementation of these systems is an important field of research. This concept proposes a novel approach to these systems, 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

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architectures. The interactive hybrid system 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 interactive system for monitoring and optimization of machining processes. It is very significant for the development of new effective and flexible manufacturing methods.

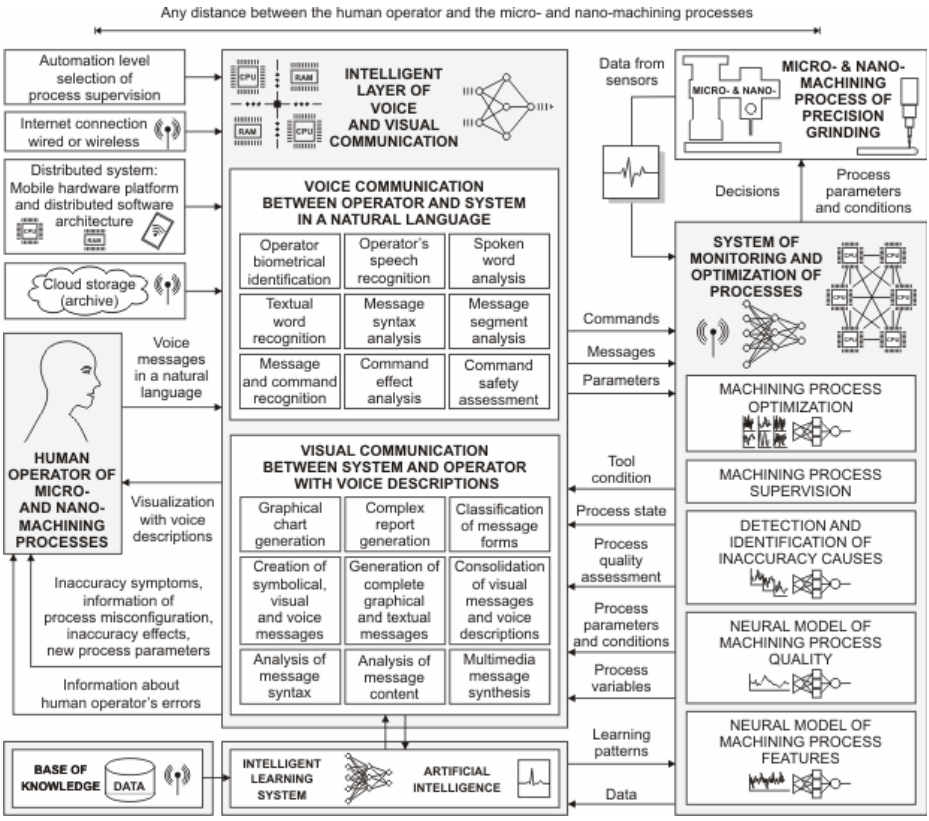

Fig. 1. Concept of interactive systems for monitoring and optimization of micro- and nano-machining processes

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 [1–4, 16]: modeling of process features and quality, assessment of inaccuracy effects, identification of inaccuracy causes, optimization of process conditions

and parameters. These bottlenecks can occur as a result of the mass production of custom products.

This article offers an approach by using the developed concept of the interactive hybrid system of monitoring and optimization of the processes of micro- and nano-machining to deal with the above problems. Selected article [4] presents innovative solutions in supervision of precise grinding processes and development of a system for monitoring, optimization and forecasting of machining process quality. Articles [5–15] describe the developed solutions in intelligent voice communication between human operators and technical devices.

3 Description of the System

The developed concept proposes an architecture of the interactive hybrid system for monitoring and optimization, which is 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 structure of the system is presented in abbreviated form on Fig. 2. The numbers in the cycle represent the successive phases of information processing. The developed concept also includes the system for mobile technologies (Fig. 3). 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 inaccuracy results, compensation of the inaccuracy results, and selection of the machining parameters and conditions. The core of the system consists of the following process models: 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 system contain probabilistic neural networks (Fig. 4) for forecasting the state of the abrasive tool and prediction of the surface quality. The inputs of the networks include parameters of abrasive tools, workpiece parameters, geometric and kinematic parameters, process variables. The system also consists of mechanisms (Fig. 5) for meaning analysis 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.

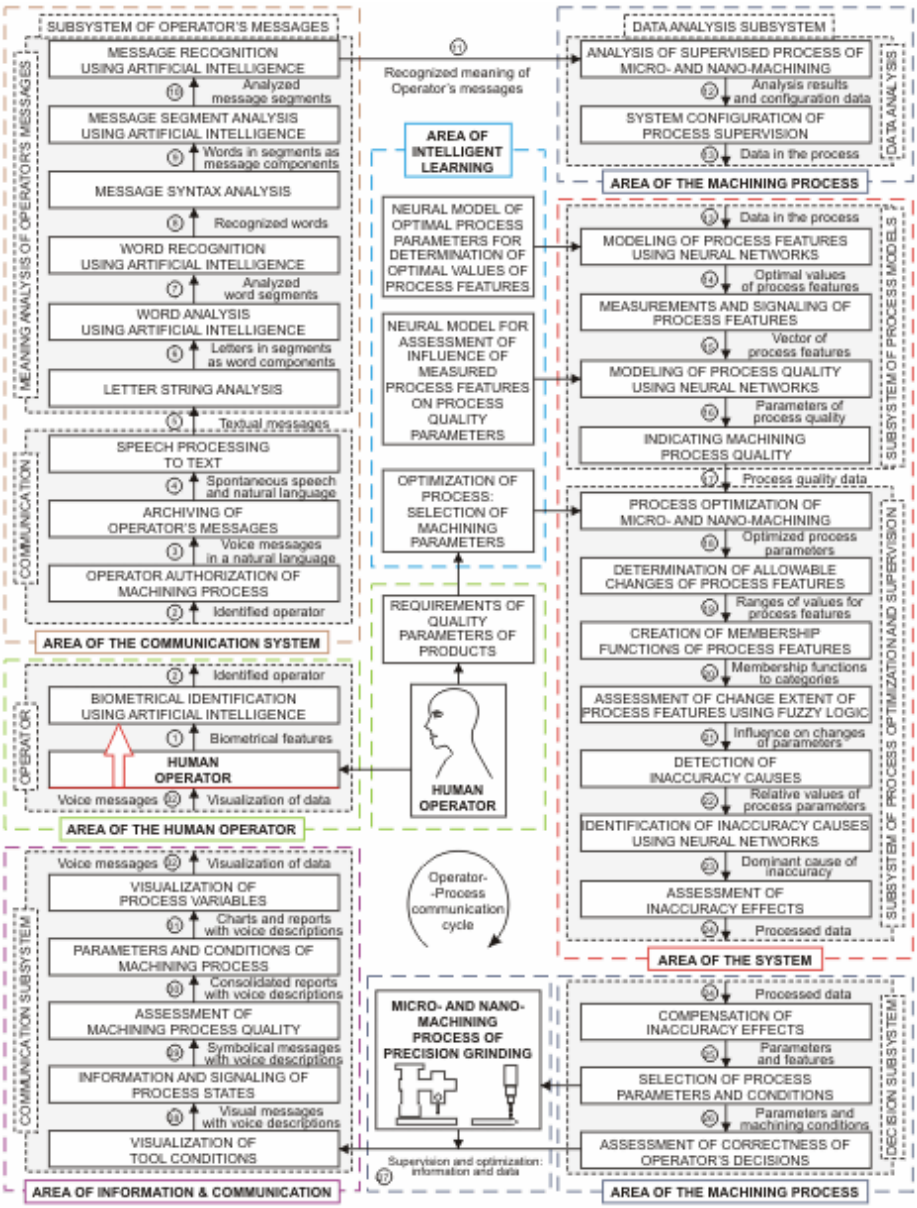

Fig. 2. Implementation structure of hybrid systems for monitoring and optimization of micro- and nano-machining processes using voice and visual communication

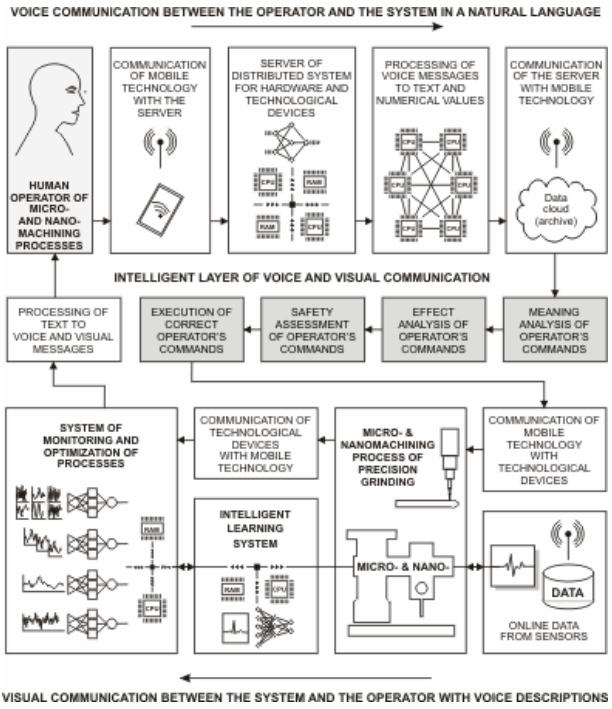

Fig. 3. Interactive system for monitoring and optimization using mobile technologies

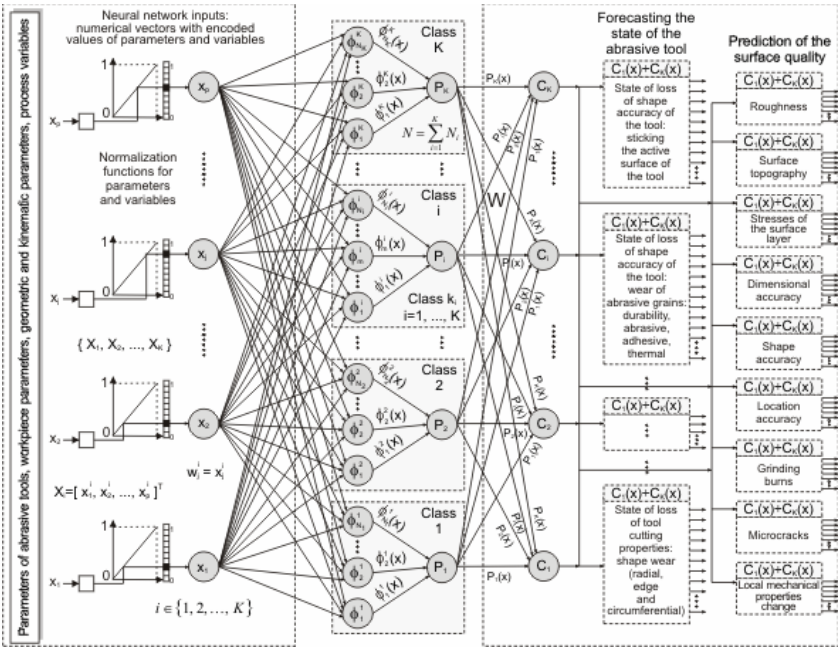

Fig. 4. Probabilistic neural networks for monitoring and optimization of processes

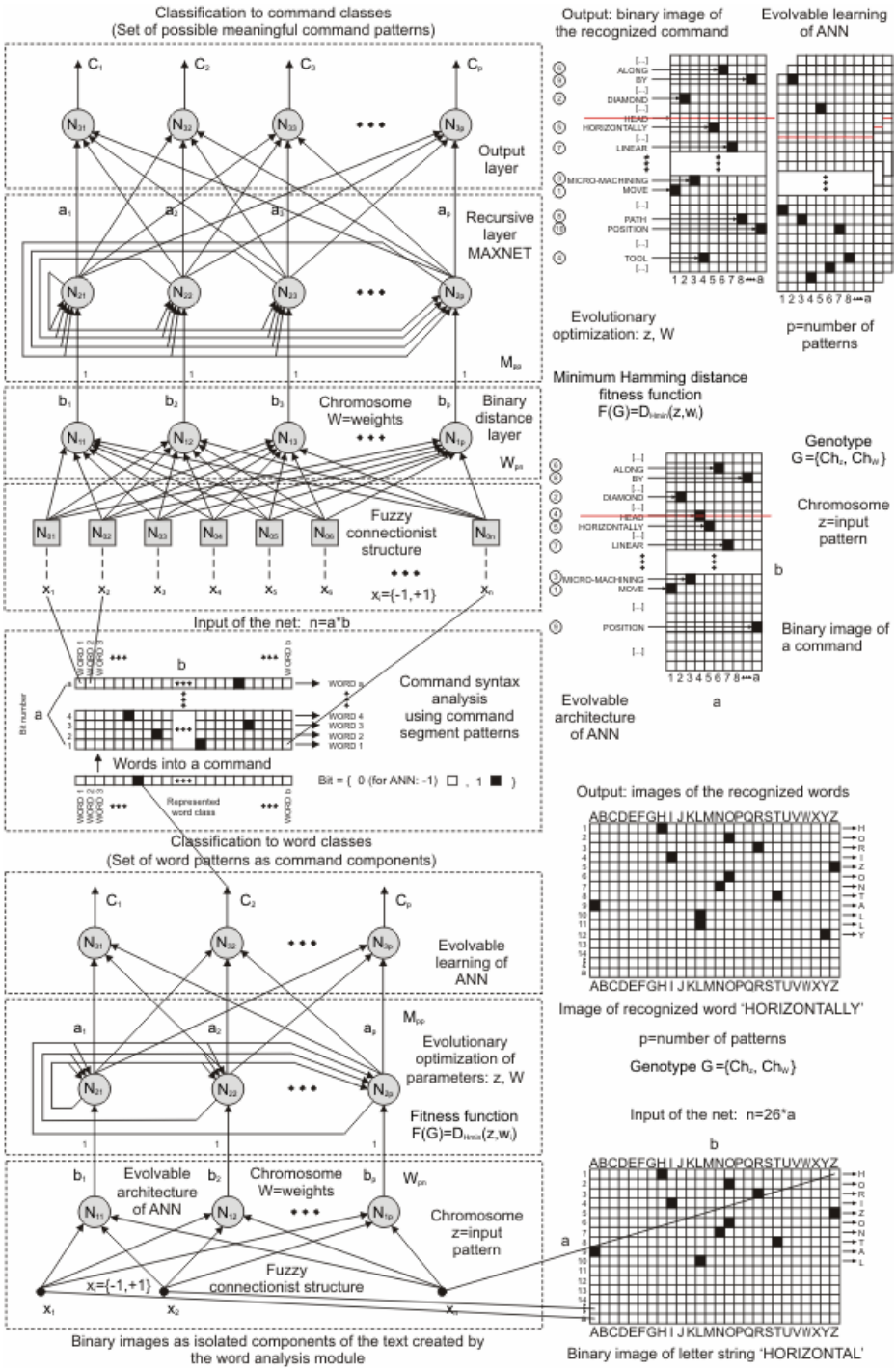

Fig. 5. Evolvable fuzzy neural networks for word and command recognition

4 Experimental Results

On the basis of experiments and extensive analysis of their results, specific requirements have been set in terms of system components and their functions. The results obtained experimentally, supported by analysis, allowed for the development of a detailed system architecture.

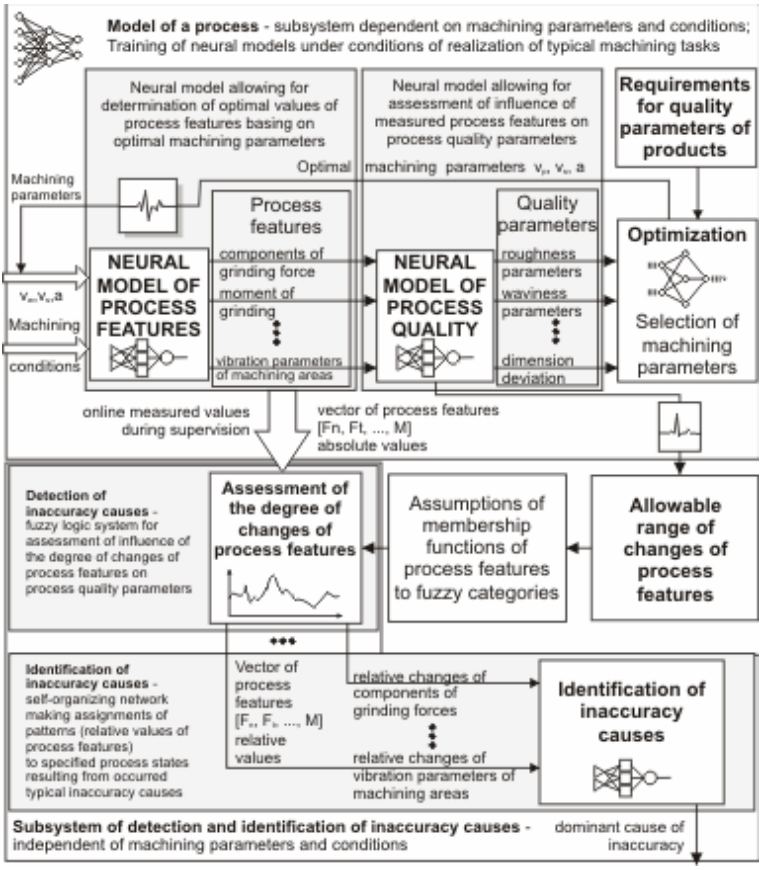

Fig. 6. System for detection of inaccuracies and optimization of machining parameters

Basing on the research, the neural models of the process features and quality have been developed for a subsystem (Fig. 6) for detection of inaccuracies and optimization of machining parameters.

The research allowed to develop the architecture of the following system presented in Fig. 7. The system preferably should contain adaptive intelligent layers for data analysis, supervision and decision. The system should be 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 inaccuracy results, compensation of the inaccuracy results, and

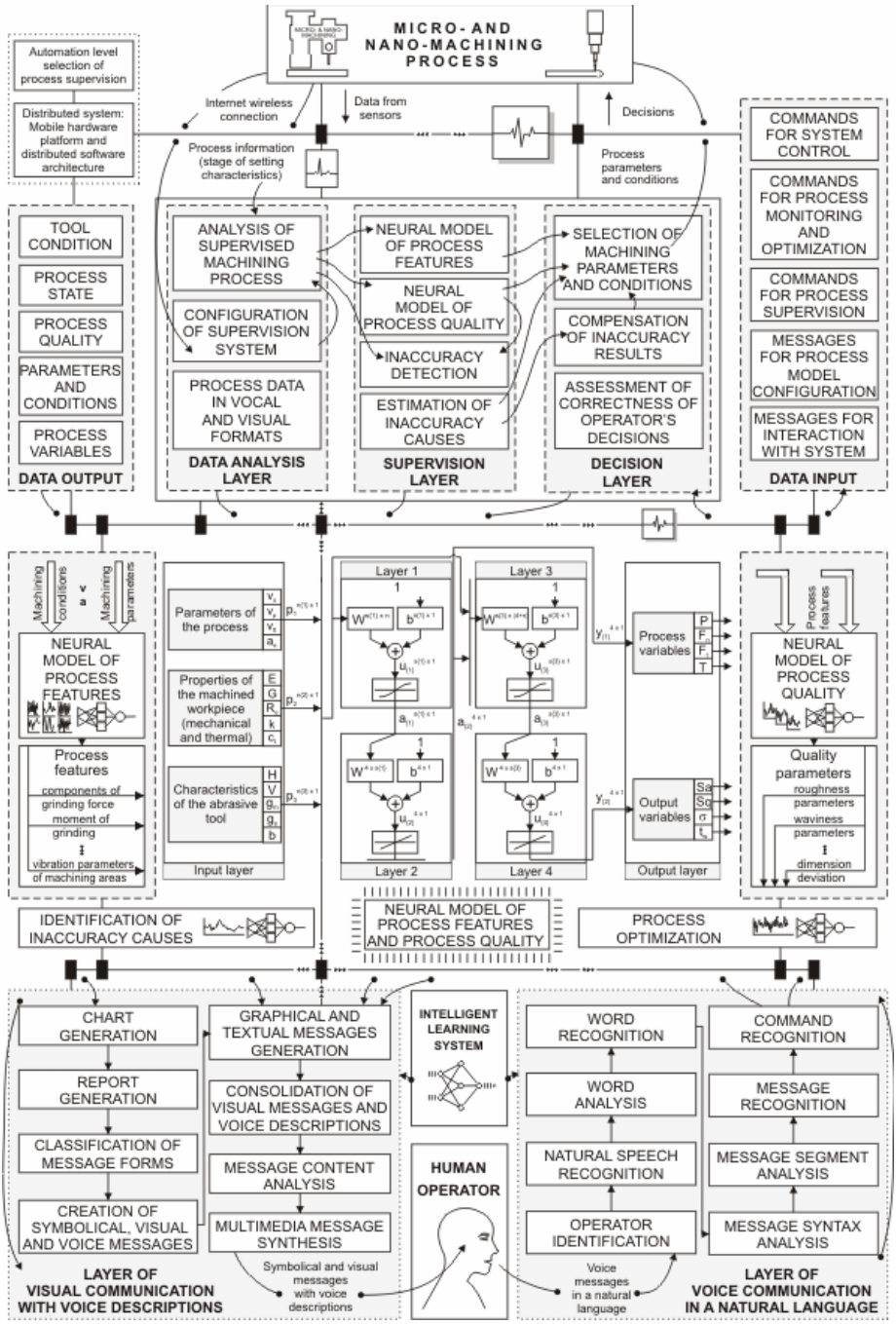

Fig. 7. The developed architecture of interactive hybrid systems for monitoring and optimization of micro- and nano-machining processes with the core of neural models of the process features and quality

selection of the machining parameters and conditions. The core of the system consists of the following process models: 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.

5 Conclusions and Perspectives

The proposed concept of the interactive hybrid systems for monitoring and optimization of machining processes, equipped with a speech interface and artificial intelligence, allows for the development of universal and intelligent systems which are independent of a type of manufacturing process, machining parameters and conditions. The condition of effectiveness of the system is to equip 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. It features the universality of application of the developed artificial intelligence algorithms. The hybrid system 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.

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