Selected problems of automatic evaluation of commands given by the operator using artificial neural networks

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Abstract

The voice communication between technological devices and the operator becomes a stronger challenge as technology becomes more advanced and complex. New applications of artificial neural networks are capable of recognition and verification of effects and safety of commands given by the operator of the technological device. In this paper there is a review of the selected issues on estimation of results and safety of the operator's commands as well as supervision of the technological process. A view is offered of the complexity of effect analysis and safety assessment of commands given by the operator using neural networks. The first part of the paper introduces a new concept of modern supervising systems of the technological process using an intelligent layer of two-way voice communication between the technological device and the operator and discusses the general topics and issues. The second part is devoted to a discussion of more specific topics of the automatic command verification that have led to interesting new approaches and techniques.

Keywords: Speech, Voice Communication, Command Evaluation, Artificial Intelligence, Artificial Neural Networks, Human Machine Interface.

I. Modern Supervising Systems of the Technological Process

According to the new concept of the modern supervising systems of the technological process in Figure 1, the operator may stay away from the technological device in another room, or even in any distance from it [9]. It is made possible by using the intelligent two-way voice communication system between the technological device and the operator. The conditions for effectiveness of that system include the following:

1) Automatic recognizing of the typical condition of the technological process with the intelligent data analysis system.
2) Permanent self-learning while working [10].
3) Informing the operator by voice about the results of automatic analysis of the process states.
4) Recognizing the operator's voice commands in continuous speech filtering with the command syntax and meaning analysis module.
5) Checking if the operator's commands are understood and not contradictory with the safe process state system - assessment of a grade of affiliation of the command to the correct command category.
6) Correcting the operator's incorrect commands with an optional condition of confirmation.

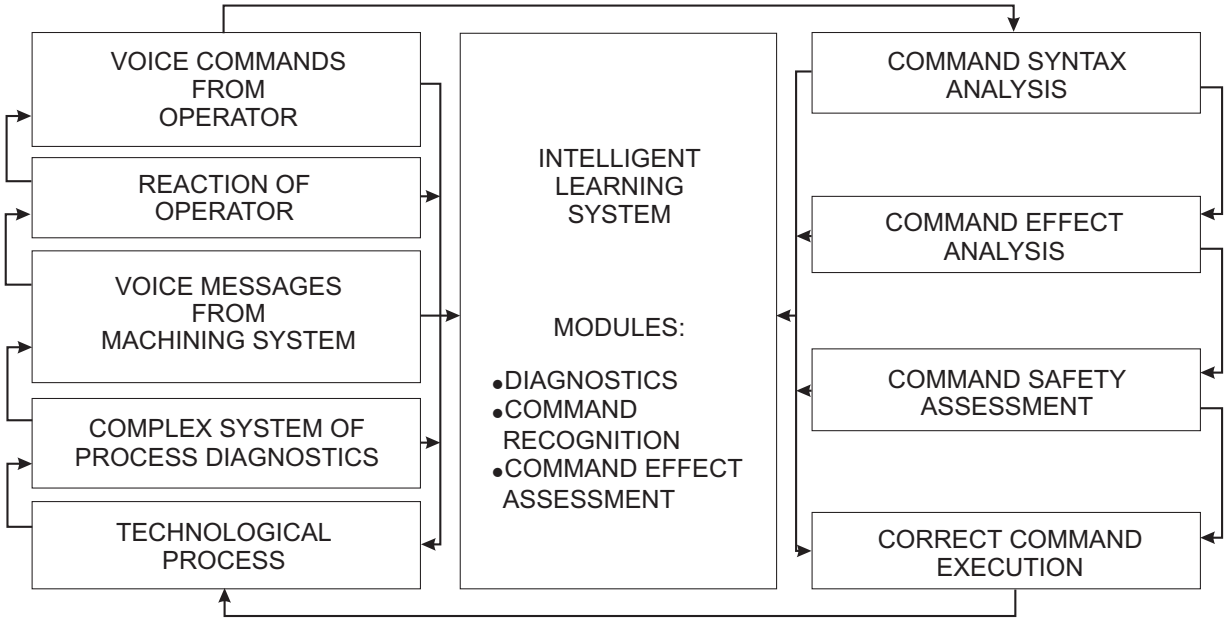

Figure 1: General scheme of the modern supervising system of the technological process

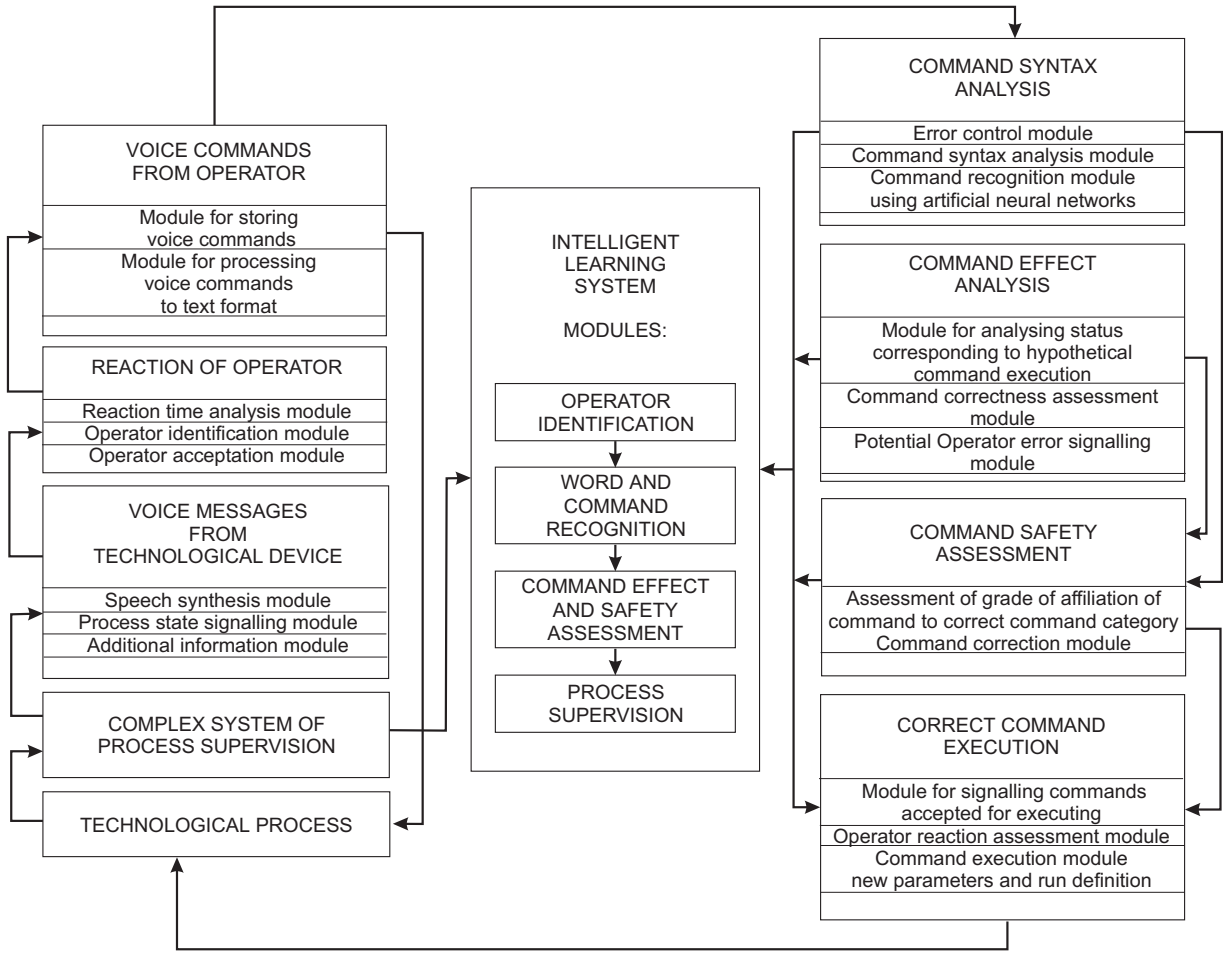

Figure 2: Scheme of the supervising system of the technological process using the intelligent layer of two-way voice communication system between the technological device and the operator

In the future in the production systems the operator will be separated from the technological devices with the intelligent layer in Figure 2, which will provide the system with more resistance from the operator's errors and much more efficient supervising of the process. The task of the supervision system of the technological process is to provide with automation and a high level of effectiveness of process supervision with an elastic and controlled co-operation of the operator observing directly or in a distance. The comprehensive supervision system of the technological process is equipped with the self-learning and self-control mechanisms. It consists of the following subsystems:

1) Process supervision.
2) Prognosis of the process state.
3) Analysis of causes and results of inaccuracy in the process.
4) Voice communication between the system and the operator [4,6,8].
5) Analysis of syntax, as well as a subsystem of estimation of results and safety of commands given by the operator.

Voice communication between the technological device and the operator is a very important element of the comprehensive supervising system of the technological process as a new user interface. The interactions of the system with the operator can be divided for the sake of function into the following categories:

1) Informing the operator about specific events while realizing the technological process,
2) Confirming results of the operator's actions [12,13,14],
3) Giving information about changing of the technological process state due to the operator's actions,
4) Providing the operator with information about the selected process states and steps,
5) Analyzing, controlling and completing the commands, monitoring of the task in action [1,11].

II. Intelligent Two-Way Communication by Voice

The advantages of intelligent two-way voice communication between the technological devices and the operator in Figure 3 include the following:

1) More resistance from the operator's errors and more efficient supervising of process with the chosen level of supervision automation.
2) Elimination of scarcities of the typical co-operation between the operator and the technological device.
3) Reaching a higher level of organizing realization of a technological process equipped with the intelligent two-way voice communication system, which is relevant for its efficiency and production humanization.
4) No need of an operator being present at the work stand by the technological device (any distance from the technological device).

The task of the intelligent two-way voice communication system between the technological device and the operator is generating voice messages to the operator about the process state, storing the operator's voice commands, analyzing reaction time of the operator, analyzing syntax and assessing safety of the operator's commands, and also estimating the operator's reaction. That system in co-operation with the comprehensive supervision system will also make it possible to analyze the state of the process corresponding to the hypothetical execution of the operator's command.

The intelligent two-way voice communication layer between the machining system and the operator consists of the following subsystems in Figure 4: subsystem of passing voice messages from the machining system to the operator, subsystem of analysis of the operator's reaction, subsystem of passing voice commands from the operator, subsystem of analysis of command syntax, subsystem of analysis of command effect, subsystem of assessment of command safety, subsystem of execution of the correct command, subsystem of intelligent learning.

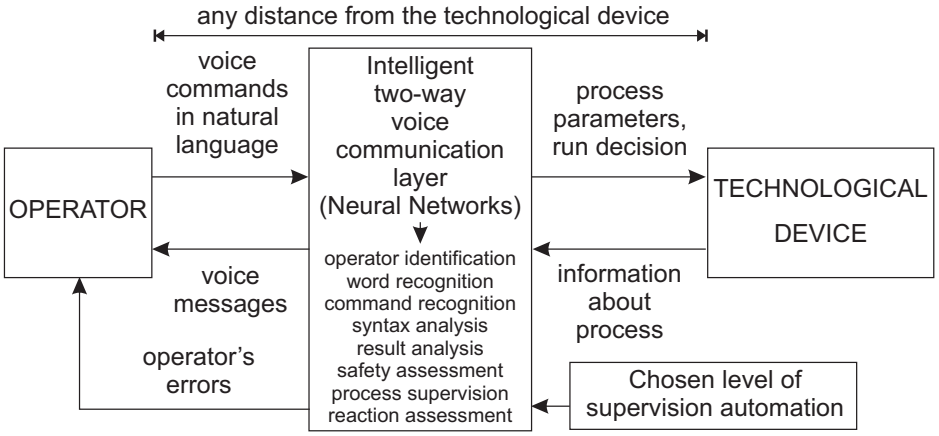

Figure 3: General scheme of intelligent two-way voice communication between the technological device and the operator

The proposed intelligent layer of two-way voice communication between the technological device and the operator is presented in Figure 5. It is equipped with the following intelligent mechanisms: operator identification, recognition of words and complex commands, command syntax analysis, command result analysis, command safety assessment, technological process supervision, and also operator reaction assessment.

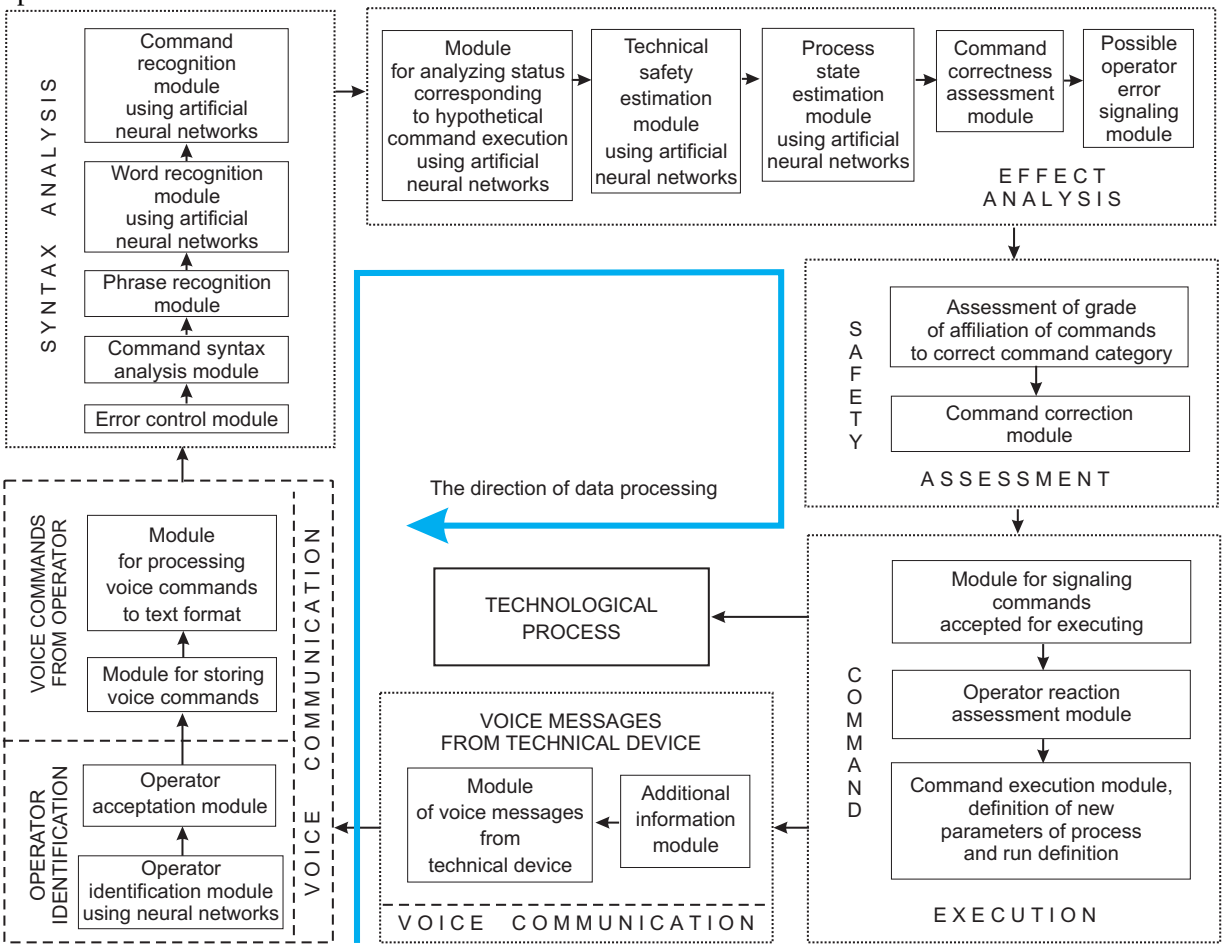

Figure 4: Scheme of the intelligent layer of two-way voice communication

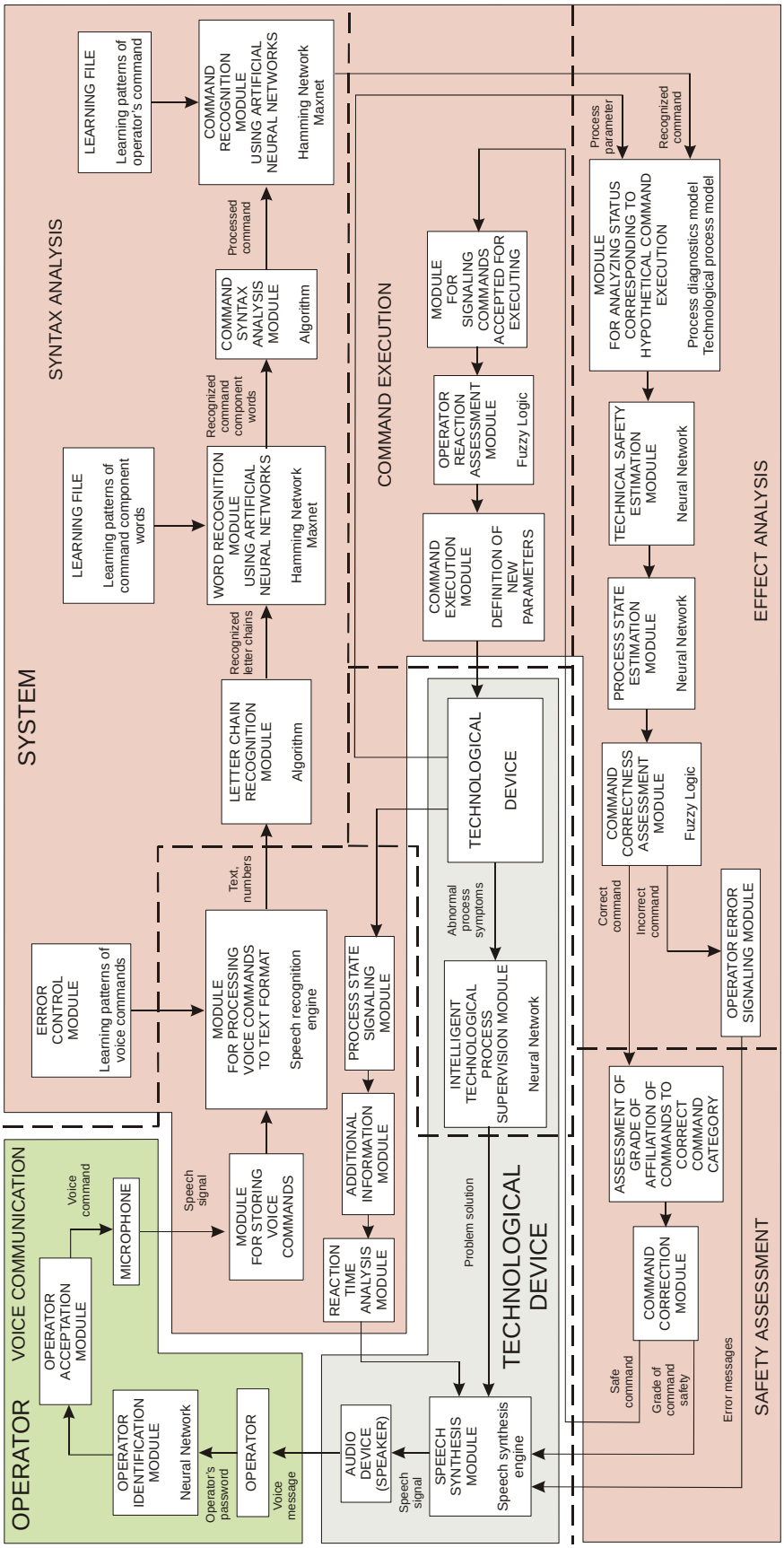

Figure 5: Architecture of the intelligent two-way speech communication system

III. Command Safety Estimation

The recognized command given by the operator is processed and sent from the command syntax subsystem to the verification subsystems of effects and safety [2,3,5,7]. The effect analysis module, shown in Figure 6a, makes analysis of the recognized command. The technical safety of the technological device is checked by analyzing the state of execution of the commands required to have been done as well as the commands to execute in next decisions. The process parameters to be modified by executing the command are checked and the allowable changes of the parameter values are determined. The analysis of the parameter values is based on the technological process features. The values of the parameter changes are the input signals of the neural network of the process state assessment system. The neurons of the neural network represent solutions to the diagnostics problem. The neural network also makes an estimation of the grade of safety of the recognized command. The system for checking the state of the automatic device for grinding of small ceramic elements that is shown in Figure 6c, before executing next commands is presented in Figure 6d. The technological safety assessment system, shown in Figure 6b, is based on a neural network which is trained with the model of work of the technological device.

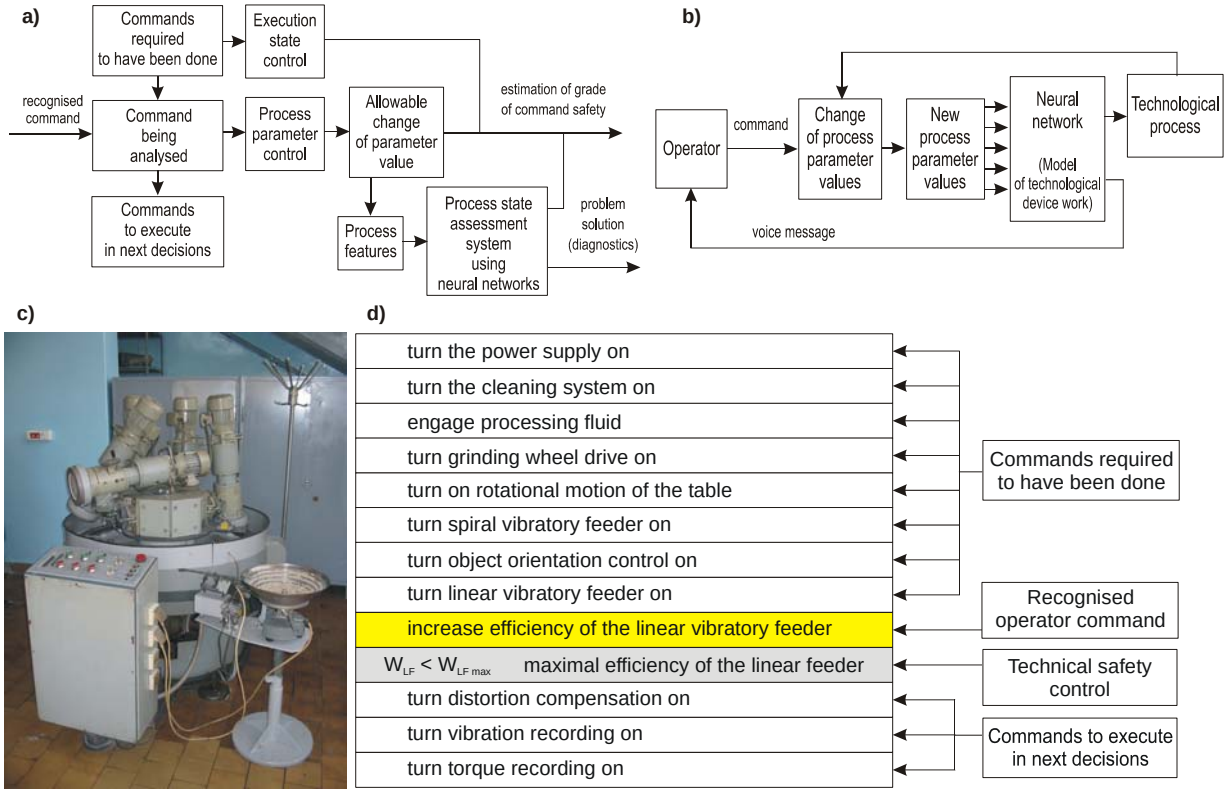

Figure 6: Scheme of the command effect analysis and safety assessment system

New values of the process parameters are the input signals of the neural network. As the work result of the system, voice messages from the technological device to the operator about the possibility of executing of the command are produced.

IV. Technological Safety of Commands Based on the Real Process

There was an algorithm created for assessing the technological safety of commands. In Figure 7, the lines present dependence of the force on the grinding process parameters for particular grinding wheels.

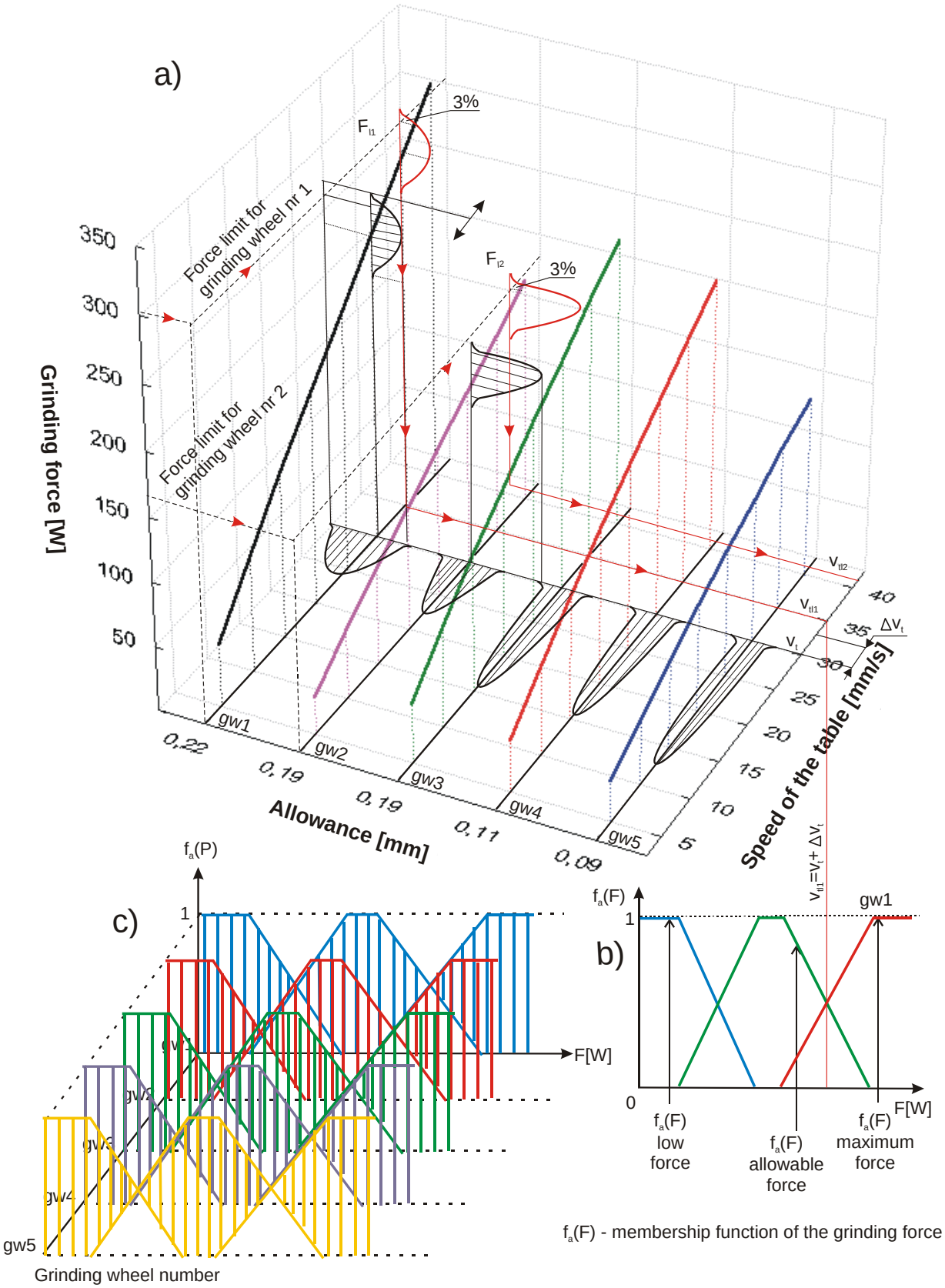

Figure 7: Algorithm for assessing the technological safety of commands based on the real technological process

Basing on the specified criteria, there is the grinding force limit determined for each grinding wheel. Basing on the grinding force limit, there is the table speed limit assigned. According to the operator's command, if the increase of the speed makes a speed of the table smaller than the smallest speed determined from the force limit for all the grinding wheels, then the command is safe to be executed.

V. Research results

The simulation set of the technological device diagnostics and the process state assessment, built for creating and training artificial neural networks is shown in Figure 8a. The neural networks are trained with the model of the technological process. The applied neural network architecture is presented in Figure 8b. The networks consist of two layers of neurons with the competitive mechanism.

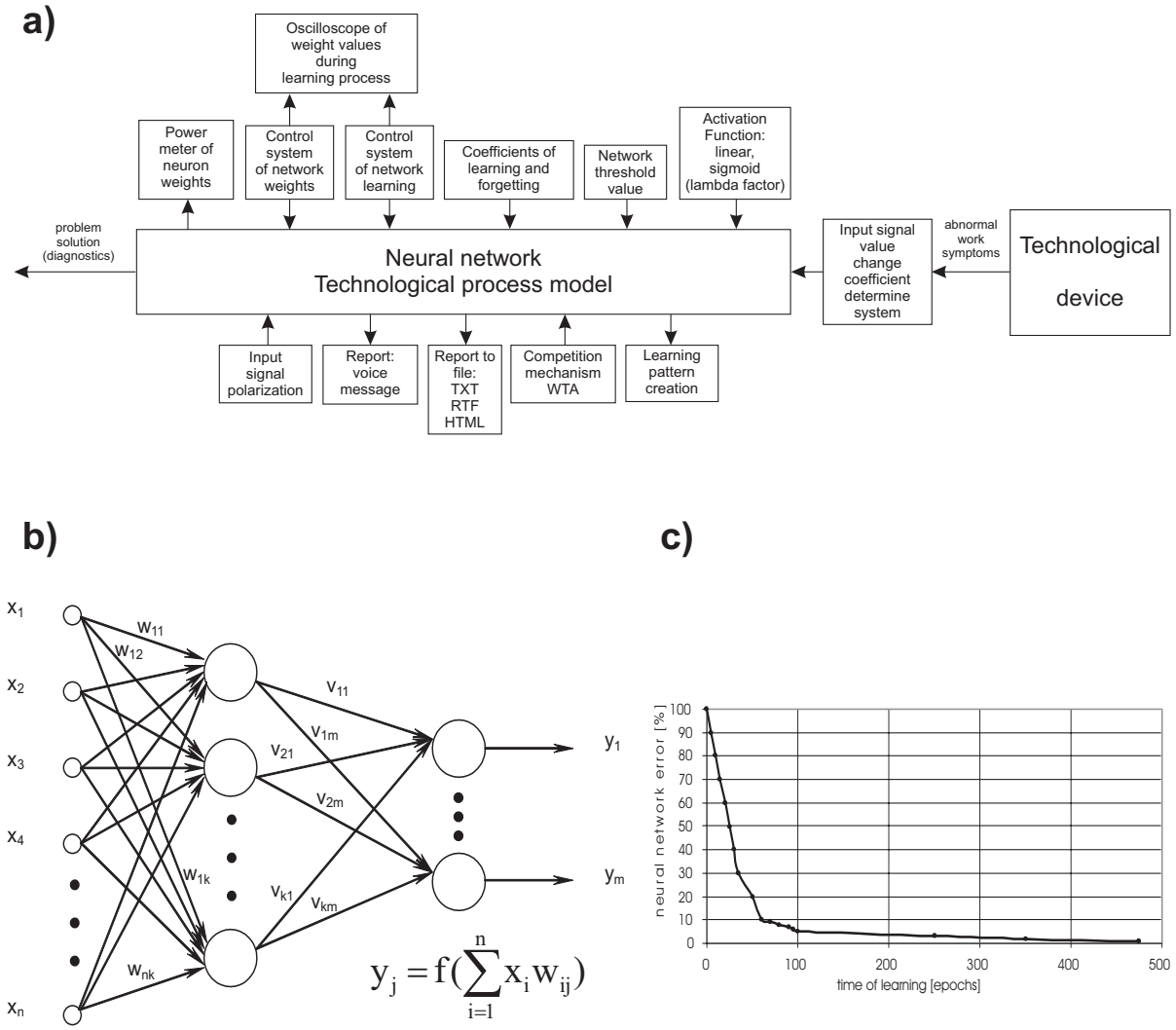

Figure 8: Neural network simulations of the technological process models, neural network architecture and error rate

The ability of the neural network to learn to recognize specific process states depends on the number of learning epochs. The specified time of learning enables the network to minimize the error so that it could work more efficiently. Based on the research, the following conclusion has been reached as shown in Figure 8c.

The error is about 20% at learning time equals 50 epochs and 5% at 100 epochs. The error has been dropped for about 90% after training with 60 series of all patterns.

VI. Conclusions and Perspectives

In the future, voice messages in natural language will undoubtedly be the most important way of communication between humans and machines. Great progress is made in many fields of science, where communication between the technological devices and the operator is an important task, e.g. motorization, road traffic, etc.

Nowadays technological devices can already be provided with enough intelligence to understand and act appropriately on voice commands. The voice communication with technological devices becomes a stronger challenge as technology becomes more advanced and complex.

The condition of the effectiveness of the presented intelligent two-way voice communication system between the technological device and the operator is to equip it with mechanisms of command verification and correctness. In the automated processes of production, the condition for safe communication between the operator and the technological device is analyzing the state of the technological device and the process before the command is given and using artificial intelligence for assessment of the technological effects and safety of the command.

In operations of the automated technological processes, many process states and various commands from the operator to the technological device can be distinguished. A large number of combined technological systems characterize the realization of that process. In complex technological processes, if many parameters are controlled, the operator is not able to analyze a sufficient number of signals and react by manual operations on control buttons.

The research aiming at developing an intelligent layer of two-way voice communication is very difficult, but the prognosis of the technology development and its first use shows a great significance in efficiency of supervision and production humanization.

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Wojciech Kacalak was born in Zdunska Wola, Poland. He obtained his doctor's degree in 1974 and as of 1989 he has been professor of technical sciences. Since 1970 he has been working at the Mechanical Faculty of the Technical University of Koszalin doing research on optimization of manufacturing processes using artificial neural networks.