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Software development for Industry 4.0 neuroprocessor industrial automation systems

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Abstract. The paper discusses the issues and problems of applying multiprocessor computing systems in Industry 4.0 industrial automation systems. The examples of tasks that are effectively solved with their help are shown: control and diagnostics tasks, rolling production tasks, sign identification problems. The developed software is considered in the form of the NP Studio software platform for the development, operation and optimization of industrial automation systems. The block diagram of the software platform and the functionality of each of the subsystems are described. An example of using the neuroprocessor system for the implementation of the hexapod control task is shown.

1. Introduction

Currently, there is a gradual introduction of cyber-physical systems in production, which implies Industry 4.0 [1]. Some of the signs of the transition to Industry 4.0 are as follows: work with big data, which requires efficiently functioning software and hardware; transition to the Internet of things; the use of autonomous robotic installations, which also require high-speed and energy-efficient computing equipment and specialized software.

For efficient operation of industrial production, neuroprocessor systems are increasingly being used.They can be applied for the following processes [2-4]:

- Classification of images. In this case, the task is to indicate that the input image (object) represented by the image belongs to one or several predefined classes of objects;
- Clustering. The clustering algorithm is based on the similarity of images and places many similar images in one cluster. This is not necessary in the pre-training of neural networks, and the problem can be solved in real time;
- Approximation of functions. The task of approximation is to find the estimate of the unknown function, distorted by noise;
- Extrapolation of functions, realizing the prediction of the situation at some future point in time.
- Optimization. The task is to find a solution that satisfies the constraint system and maximizes or minimizes the objective function. These are mainly linear programming tasks applied to production;
- Management in fuzzy situations.

However, currently there are a number of problems that prevent the more active use of

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neuroprocessor devices for automating some production processes. One of the problems is a small amount of software for a sufficiently narrow class of computing technology - neuroprocessors.

The aim of the work is to create effective software for the creation, operation and optimization of neuroprocessor automation systems for industrial production.

2. Tasks of Industry 4.0 automation

Neuroprocessor systems can be applied in cases with the following tasks [5-7]:

- Emulating an artificial neural network;
- Operations are represented in the neural network logical basis.

We will consider a few examples of such tasks:

Tasks of control and diagnostics. As the volume of automation of technological processes grows, the volumes of requirements for reliability, safety, accuracy and speed of automation systems increase simultaneously, which, in turn, increases the value of monitoring and diagnostics. Methods of classical mathematics sometimes turn out to be insufficiently accurate due to difficult technological situations, and developers of diagnostic devices resort to new technologies, among which, along with digital data processing methods, artificial intelligence methods occupy a serious position: expert systems, methods of fuzzy logic and evolutionary modeling, cluster analysis , artificial neural networks.

Rolling production. The use of neuroprocessor devices can improve both the modeling of rolling processes and the adaptation of control processes. With their help, operations are implemented to control the geometric dimensions of rolled products, optimization of the dynamic modes of operation of electric drives of the mechanisms of rolling mills, control of cutting modes, etc.

The system of identification of mobile objects. The problem consists of reading information from moving objects, including those that do not have autonomous power sources. The task is transformed into a character recognition task (number, place of registration, date of the last inspection, information generated on the car, etc.) from the image.

3. Software for work with neuroprocessor parallel systems of Industry 4.0 automation

For the implementation of software for neuroprocessor systems, the NP Studio software platform was developed. The programming language was chosen to be C# due to its robustness, independence from hardware, independence from the operating system, the ability to create a modern interface, and a high level of code optimization. The development environment was chosen as the Visual Studio 2012 programming, developed by Microsoft [8].

Initial codes include about 170 thousand lines of program code located in 204 modules. 2 external dll libraries have been developed: NeuroProc, containing the class of the model of the functioning of the neuroprocessor of the NM640x family and Config, including the settings of the complex and the functions of access to the real processor (emulator).

The interface of the complex is similar to the interface of Microsoft Visual Studio 2012, it is multidocumentary and consists of 3 parts:

- Navigation area (for switching between instances of modules);
- Area of system messages and output (for system messages when working with the program and output data of external programs);
- Workspace (to represent instances of modules).
- The program complex can be used for:
- Modeling of the neuroprocessor and/or neuroprocessor complex;
- Analysis of the effectiveness of the neuroprocessor complex and a separate processor module for a given program;
- Organization of information processing and optimization of programs with a high degree of neurobasis commands;

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- Structural design of the neuroprocessor complex;
- Choice of element base;
- Parallelization of the program code in the languages of the neuroassembler;
- Access to the neuroprocessor;
- Visual programming for the neuroprocessor complex;
- Development of programs in neuroassembler languages;
- Debugging of programs written in neuroassembler languages;
- Assistance in developing a program for the neuroprocessor;
- Learning languages neuroassembler.

The structural diagram of "NP Studio" software platform is presented in figure 1.

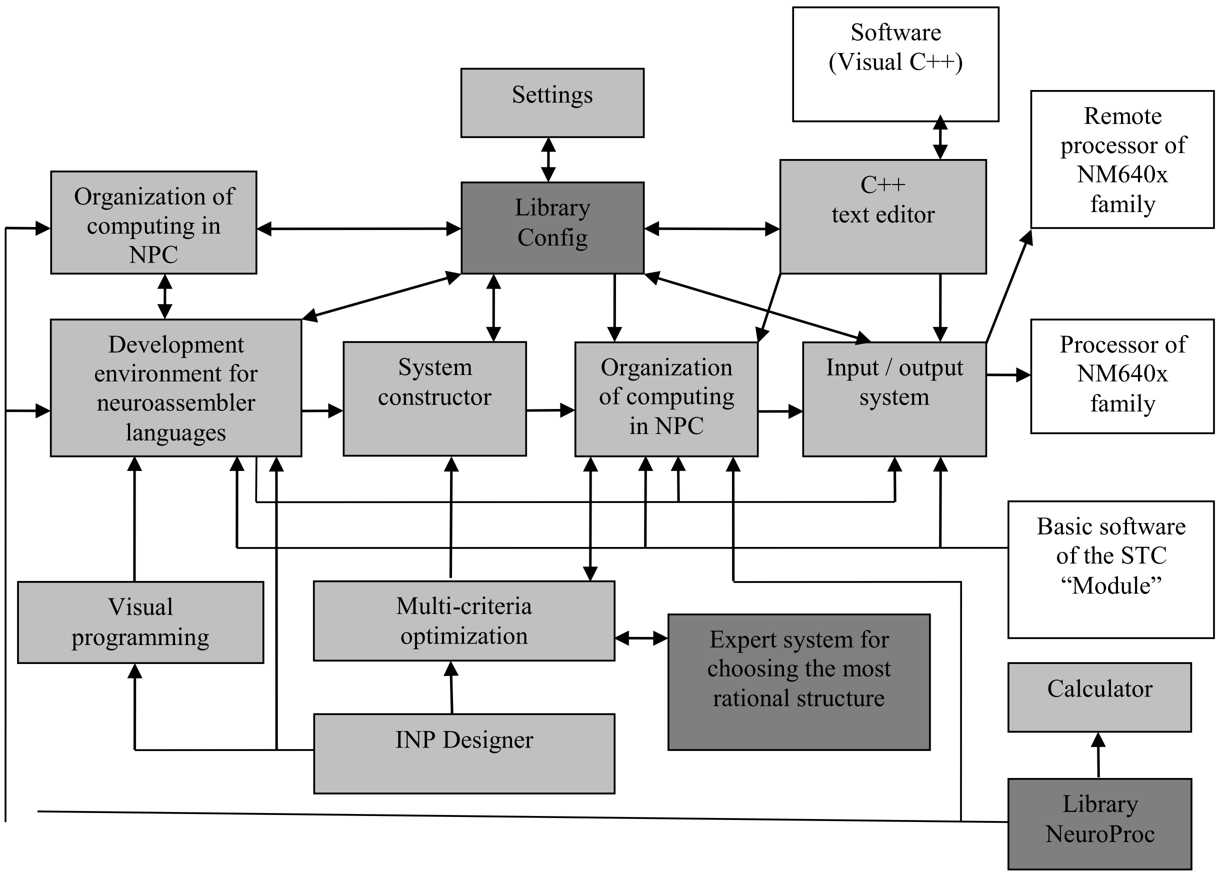

Figure 1. The scheme of "NP Studio" software platform.

Let us consider the capabilities of "NP Studio" software platform for the organization of neuroprocessor automation systems for industrial production.

When you start the program, you are prompted to enter the name of the project, in the settings you can specify the model of the device on the basis of which the multiprocessor system functions. At the moment, it is possible to choose the following devices: NM6403, NM6404, NM6405, NM6406, emulators of NM6403, NM6405 processors, instrumental boards MC 4.31, MC 53.01, MB 77.07.

To create and edit source files in C++ and neuroassembler, two subsystems are implemented: "Text editor for neuroassembler languages" and "Text editor for C++ language". For input of initial data and generation of the neural-assembler code of typical topologies of artificial neural networks, the INS Designer subsystem has been developed. To eliminate programming errors and more effective organization of the code through the use of ready-made templates of subroutines, a visual programming subsystem is implemented. Software modeling and analysis of the effectiveness of the organization of information processing in the neuroprocessor are implemented in “Organization of calculations in the NPVM” subsystem. This subsystem allows you to analyze the organization of information processing in the neural processor when executing a command without running on a real processor. To select and graphical representation of the structure of the neuroprocessor complex, the subsystem “Designer of multiprocessor systems” is implemented. To implement the analysis of the effectiveness of the organization of information processing in the neuroprocessor complex, “Organization of calculations in the NSAID” subsystem has been developed. The initial data for the analysis are: the source code of the program, additional C++ code (optional) and the system architecture. For the implementation of the optimization mechanism, taking into account the set of criteria, the “Multi-criteria optimization of the NWPC” subsystem has been developed.

One of the most important subsystems is the "Input-output system" for running the program code on a real neural processor. The functions of working with the processor are:

- Functions for the Host part (computer): showing the version of the communication library; set waiting time; get the number of modules available; getting the device's rip-desk; handle descriptor; reboot the device; loading initialization code; getting a processor access descriptor; determining the status of the device; sending an interrupt to the processor; closing the access descriptor; loading and execution of the program; synchronization with the nm process (array); synchronization with the nm process (scalar); memory entry; reading from memory; device reboot and initialization;
- Functions for the NM part (processor): determining the number of the processor; synchronization with the host-process (array); synchronization with the host process (scalar).

4. Application of the developed software

As an example, the task of controlling “smart” electromechanical devices, in this case, hexapods, can be considered [10]. The task of managing a dynamic object assumes the presence of two modes of operational and non-operational, due to the stringent requirements of processing large amounts of information at a high rate. In real time, two main tasks should be solved: the calculation of the control action and the integration of a system of differential equations. Reducing the system of differential equations to a system of algebraic equations in vector-matrix form is convenient for its implementation by means of digital computing in a special computing device, in the processor unit of which the “multiply with accumulation” operations must be performed simultaneously on several operands. Therefore, for the implementation of mathematical, algorithmic and software, it was decided to use a specialized hardware base: neuroprocessor systems due to several advantages of use, such as the speed of parallel processing, the presence of the operation “addition with accumulation”, high energy efficiency. As an example, the NeuroMatrix 640x family of processors was chosen, the neuroprocessors of which are produced by the Scientific and Technical Center Modul (Russia, Moscow).

The initial data for the development of algorithmic support and software are as follows:

- Description of digital sensor signals;
- Description of control signal generation algorithms;
- Mathematical model implemented as a model of SIMULINK module of the MATLAB software package.

The initial data of the developed algorithms are as follows:

- Description of sensor signals obtained by converting analog signals from a hexapod to a digital form using an analog-to-digital converter.

The output data of the developed algorithms are as follows:

- Control signals converted to analog representation through the use of a digital-to-analog converter;
- Information signals auxiliary and service character.

The implementation of the task showed the effectiveness of the use of neuroprocessor elements to control the hexapod in a mode close to real time.

5. Conclusion

As a result, it was shown that the use of neuroprocessor systems for the automation of industrial production and the transition to the fourth industrial revolution is effective (Industry 4.0). The use of neuroprocessor systems significantly expands the possibilities of using intelligent systems in various fields of human activity, including in the field of production process management. Pre-trained artificial neural networks are able to successfully solve the problems of creating expert and control systems, especially on the basis of neural systems.

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