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Approach to Programmable Controller Building by its Main Modules Synthesizing Based on Requirements Specification for Industrial Automation

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***Abstract*—The article is dedicated to the research on the implementation method for the automation controller module synthesis depending on the technical assignment to the object under control. Comparative analysis of existing solutions of similar kind is presented, a method for the controller's program modules synthesis is proposed. This method advantages at implementation and utilization are shown as well. The load test results of the proposed solution depending on the number of modules and used components in the control program are presented. The practical example of the synthesized solution to thread-grinding machine automation control is also examined.**

Keywords—automation; PLC; CNC; modular approach; flexibility; synthesis; industry

I. Introduction

Each year the computing power of microprocessor equipment increases, while the physical dimensions of computing hardware decrease. This trend results in development of software-hardware products (including control systems) based on various solutions. At the same time, there is a choice between single board computers (Raspberry, Tavolga-M) and solutions, based on the full-fledged platforms (Mini-ITX, ATX) [1,2].

Based on the research provided in this article it was concluded that it is necessary to devise a methodology for cross-platform automation controller synthesis taking into account the processing power of the chosen platform. This should benefit in two ways: 1) any fully complying technical solution could be selected by the end customer; 2) incidents that could have occurred due to the chosen platform limitations in terms of assigned tasks are being eliminated [3].

II. Analysis of the Existing Solutions for Industrial Automation

Modern control system architecture as well as industrial automation controller architecture implies that a certain software-hardware platform should be utilized [4]. At the same time, several manufacturers declare that the control system core could be ported to other platforms (see Table 1).

TABLE I. SYSTEMS CONTROL (CNC AND PAC)

Parameter	Control systems (CNC and PAC)			
	UCNC NC-400 (Balt-System)	*WinAc (Siemens)*	*MLC (Bosch Rexroth)*	*PAC AxiOMA (MSTU Stankin)*
Embedded system	Only NC-300 NC-400	With spec.app. and hw	With spec.app. and hw	Embedded/ Stand-alone
Core OS	MS-DOS	WinXP RTX	UNIX	WinXP RTX LinuxRT
Solution synthesized based on the technical assignments	n/a	Modules set before the control program launch	Modules set before the control program launch	Modules synthesized depending on control program
Self-test option	No data	Test is performed after the control program launch	Test is performed after the control program launch	Test is performed before the control program launch

Major European manufacturers (Siemens, Bosch Rexroth) are aiming at their own platform development for control systems where hardware of varying processing power and configurable software within various price range is utilized [5]. Other manufacturers such as ICPDAS, Balt-System often assemble configuration of maximum capacity based on solutions of other vendors and add their own software. Mentioned approaches result in solution excess causing extra charges.

Thus, there appears a necessity to devise a systematic approach that allows assembling minimal and sufficient configuration of hardware-software platform and applied software depending on technical assignment to the object under control [6,7]. This allows, on the one hand, decreasing of the specialized automation techniques development time, and on the other hand, providing the end user with operable solution (including the option to test all the functions before the system launch), meeting the requirements of the technical assignment to the object under control [8].

III. Systematic Approach to Building a Cross-Platform Automation Controller

This arcticle considers the synthesis of the cross-platform automation controller of technological processes with open module architecture, depending on the technical assignment to the object under control [9]. To achieve this aim there has been proposed a method including the following stages:

1. Control system optional modules choice, control program and device configuration development based on the technical assignment
2. Computing hardware-software platform performance assessment using a set of specialized tests
3. Controller synthesis using the modules set limiting function
4. Synthesized solution operability test before launch

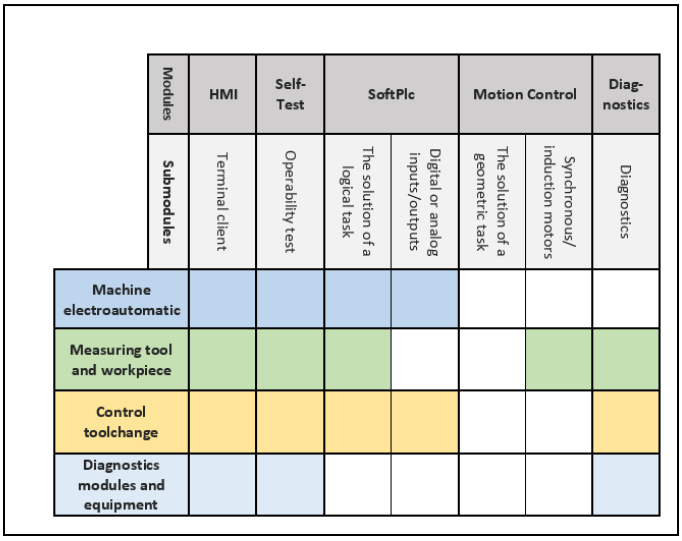

Fig. 1. Matrix of optional and mandatory program modules

At the first stage, a matrix of optional and mandatory program modules of control system is formed (Fig. 1). A set of optional modules intended for automation controller synthesis can be varied without any decrease in the quality of technological process depending on the technical assignment for the controlled object and the choice of optimal software-hardware platform implementation.

A set of specific load tests is performed in order to assess the processing power of specific software-hardware platform (Table 2). A table showing dependencies between the number of modules and the used components of the control program the can be assembled based on this test results. Maximum permissible load parameters were determined under both autonomous usage scenario and while the synthesized solution was present within the control system as an additional module.

At the third step, it is necessary to synthesize solution taking into account modules set limiting functions in conjunction with the results gathered during the first and the second steps. All the modules are represented as separate elements of the set. The submodules of the modules are elements of the same set at that.

TABLE II. Types of the Solution of Analysis and Limiting Factors

Limiting factors	Analysis type	Description (a set of specialized load tests
RAM Usage	Static Analysis	Strictly specified with expandable
CPU Load	Platform-dependent analysis	Table characteristics with subsequent approximation
Control program cycle time		
Devices response time		Depending on specific equipment configurations

Every module is a part of control system that is being synthesized i.e. technological process automation controller (see equation (1) and equation (2)).

$A = \{A_1, A_2, \dots A_n\}$, where $n \in N$ (1)

$A = \{\{A_{11}, A_{12}, \dots A_k\},\{A_{21}, A_{22}, \dots A_{2n}\}, \dots\{A_{n1}, A_{n2}, \dots A_{ns}\}\}$, where $k, m, n, s \in N$ (2)

$$\sum_{i}^{n} A_i \quad \text{where } i \in N, \qquad (3)$$

Aggregate of all mandatory modules and all optional modules meeting the requirements of the technical assignment to the object under control and to the capabilities of the software-hardware platform is considered to be total (see equation (3)).

There has been presented such an infinite set Ω where for any $A_i \in A$ and $A \in \Omega$ means, that $A_i \in \Omega$, given $i \in N$ on transitivity. Function f(x) is specified in a certain interval Ω, $A \in \Omega$ – subset of this interval, consequently f(x) is specified at every $x \in A$. Having considered values in points $x \in A$, their has been received a function, set A being its specified interval.

$$f|_A : A \rightarrow N;\ f|_A(x) = f(x) \qquad (4)$$

In equation (4) there is shown set A limiting function $f|_A$.

To assess the experiment and values approximation a decision has been taken to implement regression analysis being one of the most frequently-used techniques to process experimental data which includes least-squares methods (see equation (5)).

$$f|_A(x) = \left(\frac{n \cdot \sum_{i=1}^{n}(x_i \cdot y_i) - \sum_{i=1}^{n} x_i \cdot \sum_{i=1}^{n} y_i}{n \cdot \sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_i\right)^2}\right)x + \frac{\sum_{i=1}^{n} y_i \cdot \sum_{i=1}^{n} x_i^2 - \sum_{i=1}^{n} x_i \cdot \sum_{i=1}^{n}(x_i \cdot y_i)}{n \cdot \sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_i\right)^2} \qquad (5)$$

At stage four operating capacity of the solution being synthesized is tested. Traditional approach stipulates that after the control program has been loaded into the control system core the work is initiated. In case of marginal error e.g. element processing cycle time, the program can exit with error. The proposed variant presupposes the test performed before the work initiation in order to determine the synthesized controller operability based on the test results gathered during the second stage.

IV. Practical Use a Proposing Method of Synthesis of the Cross-Platform Automation Controller

In accordance with the proposed algorithm there has been developed synthesized solution operability test toolkit based on stage 2 results, the key objective of which is to determine if the synthesized automation controller is operable taking into account not only technical assignment to the object under control but also possible introduced corrections to the system configuration (time cycle alteration or device interrogation tact, program component increase), that can occur in the process of commissioning [10,11]. The given solution was applied at « MSZ-SALUTE» (CNC "AxiOMA Control"). For this particular NC-controlled system there has been decided to apply integrated variant of synthesized solution that was supposed to be responsible for the thread-grinding machine magnetics and measuring system, that allows to focus major calculating resources on forming assignment. It should be pointed out that for the implementation of such a project the maximum values of resources (such as CPU Load, Control Program Clock, RAM Usage) allocated for embedded solution integration were of great importance [12]. All these values were directly dependent on the number of control program components of the automation controller (see Fig.2).

This approach allowed a decrease in the magnetic subsystem and measurement system (part control system) development time by 27% (from 720 m/h to 525.6 m/h).

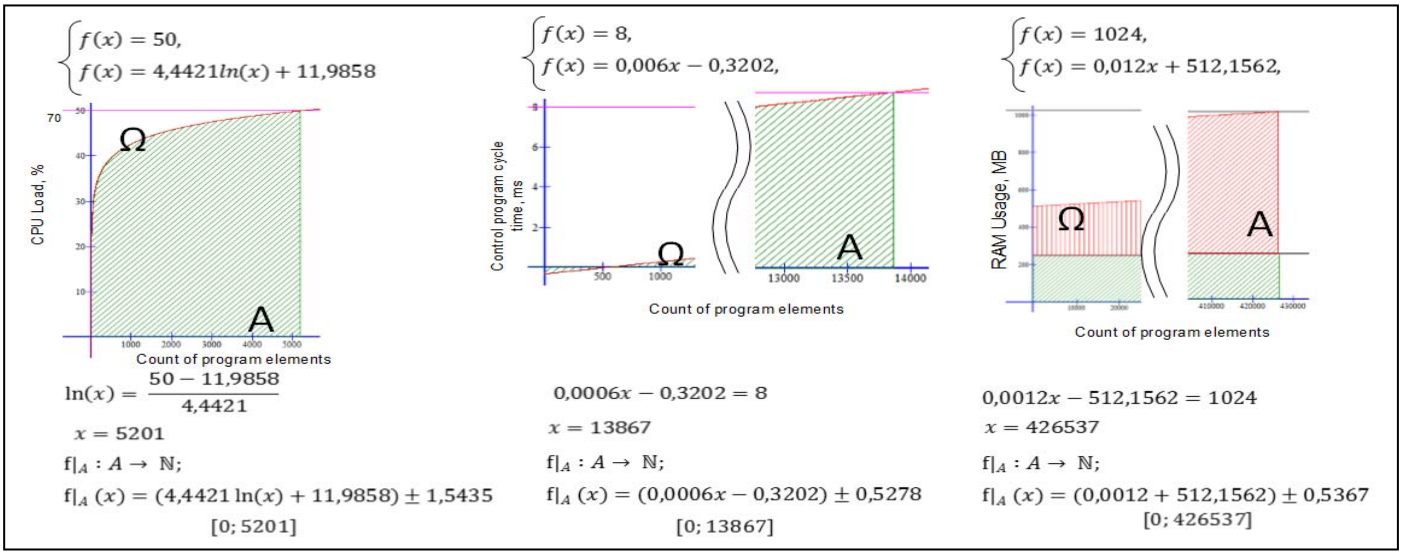

Fig. 2. Limiting functions for integrated variant of synthesized solution CNC "AxiOMA Control"

V. Conclusion

The method presented in the article allows implementing specialized solutions synthesis for technological processes automation varying on program modules set and correspondingly functional capabilities depending on technical assignment to the object under control. The proposed method can be applied when designing various control system architecture: controllers, NC-controlled systems, motion control systems, etc. It allows avoiding functions excess in the product offered to the customer to solve industrial automation tasks, which can lower its cost and spent resources, and increase offered solution efficiency due to excluding modules that are not required for a specified task. Application of this method has proved to be effective and allowed minimizing resources spent for controller embedded into NC-controller system for magnetic automation of complex machine equipment.

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