Neuro-semantic Industrial Control

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***Abstract*—This article provides a review of the current situation of ontology use in industrial control with help of OSTIS Technology, examines in more detail the issues of combining together classical approach (standards in the field of Industry 4.0, such as ISA-88, ISA-95 and ISA 5.1) and intelligent technologies (neuro-control as part of Artificial Intelligence, AI) between robots (robotic systems) and humans.**

***Keywords*—Semantic analysis, OSTIS technology, Wolfram Mathematica, Wolfram Knowledgebase, Entity, temporal markers, Nevod**

I. Introduction

This work expands on the ideas discussed in [1]– [3] and includes descriptions of current issues and new versions of suitable tools for developing and using standards in industry in relation to modern techniques (neurocontrol, semantic technologies).The connection with Industry 4.0 is taken into consideration, which is typically characterized by its complexity and the need for comprehensive knowledge of models and techniques to achieve an integrated solution [4].The arrival of Industry 4.0 has made it necessary for technical systems to consider the reliable and safe interaction of various intelligent systems with each other [5]. By using Artificial Intelligence decision making algorithms, process mapping in the new Industry 5.0 scenario can be enhanced, particularly by defining workflow checkpoints and identifying risks related to production and product quality.

The important role is played by all participants in the process: users — people (operators, masters, supervisors, etc.); devices — sensors and actuators (temperature sensors, pumps, valves, etc.); mechanized systems — conveyor systems, units; robotic systems — hinged robots, delta robots, manipulators; and software systems — SCADA, MES, ERP. Their interaction ensures the achievement of the goal, elimination and prevention of emergency situations. And important influence have both quantitative indicators (number of operators, devices, aggregates, control panels, etc.) and quality (quality of devices, qualification of operators, quality of software systems, etc.). Also important in management systems is the speed of decision-making — making changes quickly to meet plans. Each level is controlled by its own algorithms — often the element may

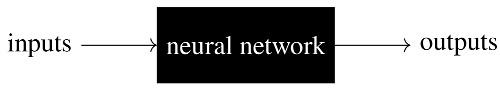

Figure 1: Neural network as a black box

look like a black box: input and output data are known, and the inputs neural network outputs Figure 1. Neural network as a black box algorithm is hidden from the user. For instance, a neural network can so be described (Fig. 1).

But if you want to have some more subtle configuration, you have to go to the documentation and use specific tools (for example, a change in the structure of the neural network may involve additional training or full new training on new reference data, which may also be unavailable and will require additional creation or/or adaptation of existing ones). The ontological description provides a general description that can be understood by all the participants. An integrated approach is needed to create a fundamentally new generation of intelligent computer systems and a corresponding technological complex.

Standardization describes different aspects of each developed human activity and includes a system of concepts (including terminology), a typology, and a model that describes how to apply appropriate methods and means, production sites, types and structures of project documents, accompanying activities, etc. With the existence of standards, we can solve one of the key problems related to any technology, particularly the rapidly developing computer information technology, **compatibility problem** [6]. Compatibility can be considered in many aspects, from the consistency of terminology in the interactions of process participants to the consistency of actions taken in the process of technology application. On the one hand, the problem with cohesion of digital twin models lies in the fact that a large number of disparate, unrelated and heterogeneous models are required. On the other hand, connecting digital twins in a single system [7] requires their interaction, and awaits conceptual unification of this interaction. It also require from Supervisory Control And Data Acquisition (SCADA) systems a higher level of integration, scalability and technological modernity [8].

Despite advances in information technology, most standards are now presented in the form of traditional linear documents or Web resources containing a series of static pages connected by hyperlinks. This approach to expressing standards has many serious drawbacks, and ultimately the overhead costs of maintaining and using standards actually outweigh the benefits of using them [9].

II. Problems and state of art

An analysis of the work has made it possible to formulate the most important and common problems related to the development and application of modern standards in various fields [9], [10]:

- Above all, the complexity of maintaining the standards themselves due to the duplication of information, especially the complexity of changing terminology.
- Duplicate information in the documentation describing the standard.
- Standards Internationalization Issues — translating a standard into multiple languages actually requires supporting and coordinating independent versions of the standard in different languages.
- As a result, inconsistencies in the format of different standards. As a result, automating the process of developing and applying standards is complicated.
- The inconvenience of using the standard, especially the complexity of finding the information you need. As a result, the complexity of studying standards.
- The complexity of automating the verification that an object or process complies with the requirements of a particular standard.
- etc.

These problems are mainly related to the presentation of standards. The most promising approach to solve these problems is the transformation of each specific standard into a knowledge base, which is based on a set of ontologies corresponding to this standard [6], [9]–[12]. This approach allows us to significantly automate the development processes of the standard and its application.

As an example, consider the **ISA-88** [13] standard (the basic standard for batch production). Although this standard is widely used by American and European companies and is actively implemented on the territory of the Republic of Belarus, it has a number of drawbacks. Essential ISA batch systems standards are:

- *ANSI/ISA-88.00.01-2010*, Batch Control — Part 1: Models and Terminology;
- *ISA-88.00.02-2001*, Batch Control — Part 2: Data Structures and Guidelines for Languages;
- *ANSI/ISA-TR88.00.02-2015*, Machine and Unit States: An implementation example of ANSI/ISA88.00.01;
- *ISA-88.00.03-2003*, Batch Control — Part 3: General and Site Recipe Models and Representation;
- *ISA-TR88.0.03-1996*, Possible Recipe Procedure Presentation Formats;
- *ANSI/ISA-88.00.04-2006*, Batch Control — Part 4: Batch Production Records;
- *ISA-TR88.95.01-2008*, Using ISA-88 and ISA-95 Together;
- *IEC 61512-1*, The European version approved in 1997, based on the older version *ISA-88.01-1995*;
- *GOST R IEC 61512-1-2016* — Russian version of the standard, identical to *IEC 61512-1*.

Another standard often used in the context of Industry 4.0 is **ISA-95** [14]. **ISA-95** is an industry standard for describing high-level control systems. Its main purpose is to simplify the development of such systems, abstract from the hardware implementation and provide a single interface to interact with the ERP and MES layers. Consists of the following parts:

- *ANSI/ISA-95.00.01-2010*, Enterprise-Control System Integration — Part 1: Models and Terminology;
- *ANSI/ISA-95.00.02-2018*, Enterprise-Control System Integration — Part 2: Objects and Attributes for Enterprise-Control System Integration;
- *ANSI/ISA-95.00.03-2013*, Enterprise-Control System Integration — Part 3: Activity Models of Manufacturing Operations Management;
- *ANSI/ISA-95.00.04-2018*, Enterprise-Control System Integration — Part 4: Objects and Attributes for Manufacturing Operations Management Integration;
- *ANSI/ISA-95.00.05-2018*, Enterprise-Control System Integration — Part 5: Business-to Manufacturing Transactions;
- *ANSI/ISA-95.00.06-2014*, Enterprise-Control System Integration — Part 6: Messaging Service Model;
- *ANSI/ISA-95.00.07-2017*, Enterprise-Control System Integration — Part 7: Alias Service Model;
- *ANSI/ISA-95.00.08-2020*, Enterprise-Control System Integration — Part 8: Information Exchange Profiles.

Models help define boundaries between business and control systems. They help answer questions about which functions can perform which tasks and what information must be exchanged between applications. The ISA5 standards development committee is often referred to as the ISA-5.1 standard among practitioners. However, the ISA5 committee, “Documentation of Measurement and Control Instruments and Systems,” has a broader scope—namely to develop standards, recommended practices, and technical reports for documenting and illustrating measurement and control instruments and systems suitable for all industries. ISA5 standards consist of the following:

- *ANSI/ISA-5.1-2022*, Instrumentation Symbols and Identification;
- *ISA-5.9 working group*, Controller Algorithms and Performance;
- *ISA-5.4*, Instrument Loop Diagrams; 166
- *ISA-5.5-1985*, Graphic Symbols for Process Displays;
- *ISA-5.6*, Documentation for Control Software Applications;

This standard is useful when a reference to equipment is required in the chemical, petroleum, power generation, air conditioning, metal refining, and many other industries. The standard enables anyone with a reasonable level of plant knowledge to read flow charts to understand how to measure and control a process without having to go into the details of instrumentation or the knowledge of an instrumentation expert.

III. Neurocontrol

Neurocontrol is a relatively young field of research that became independent in 1988. However, research in this area began much earlier. One of the definitions the science of "cybernetics" considers this as a general theory control and interaction not only of machines, but also also biological beings. Neurocontrol tries to achieve this position through the construction of control systems (decision-making systems), which can be trained during operation, and thus improve its performance. In this case, such systems use parallel mechanisms of information processing, like the brain of living organisms [15].

For a long time the idea of building a perfect control system - a universal controller that would look like a «black box» from the outside was popular. It could be used to control any system, with connections to sensors, actuators, other controllers, and a special link to the «efficiency module» — a system that determines the management efficiency based on given criteria. The user of such a control system would only set the desired result, the further trained controller would manage himself, perhaps following a complex strategy of achieving the desired result in the future. It would also constantly adjust its management based on the management object's response to achieve maximum efficiency. An outline of such a system is given below (Fig. 2).

IV. Developed Neuro-PID controller

The overall structure of the self-tuning neuro-PID controller is shown in Fig. 3, where the neural network (NN) outputs are proportional (K), integral (TI), and differential (Td) components [16].

To control the Pasteurizer [16] PID is configured with a multilayer perceptron (MLP, neuro-PID adjuster) with the following structure: 20 input, 10 hidden and 3 output neural elements; the function of activating the hidden and output layers is sigmoid (Fig. 4).

The discrete-time **PID controller** can be described by equation 1 [16], where P, T_I and T_D are proportional factors, integral and differential constituents respectively, u_n determines the input of a control object at a time of $t = nT_0$ and e_n- an error between the desired output value of r_n and the real output of $e_n = r_n - y_n$. T_0 defines a unit time interval.

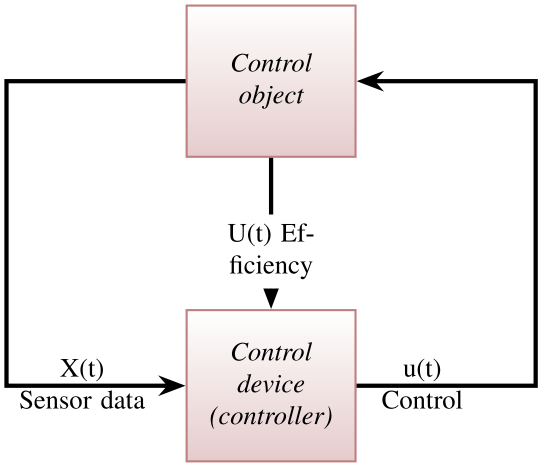

Figure 2: Reinforcement learning

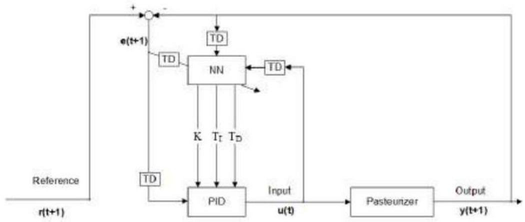

Figure 3: The developed neuro-PID controller, TD means delay operator

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\begin{aligned}
u_k &= u_{k-1} + \Delta u_k \\
\Delta u_k &= q_0 e_k + q_1 e_{k-1} + q_2 e_{k-2} \\
q_0 &= \mathbf{K}\left(1 + \frac{T_D}{T_0}\right) \\
q_1 &= -\mathbf{K}\left(1 + 2\frac{T_D}{T_0} - \frac{T_0}{T_I}\right) \\
q_2 &= \mathbf{K}\frac{T_D}{T_0}
\end{aligned}
\tag{1}
$$

Algorithm for operation of **neuro-PID adjuster** [16]:

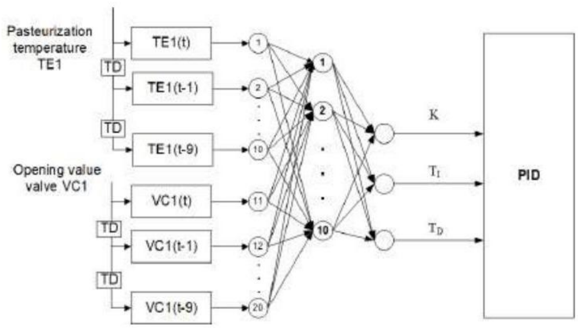

Figure 4: Neuro-adjuster PID