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Artificial Intelligence for Industrial Process Control versus Intelligent Process Control

Roxana Florina BOANDA
Transilvania University of Brașov, Romania, roxana.iamandii@unitbv.ro
Aurel FRATU
Transilvania University of Brașov, Romania, fratu@unitbv.ro

Abstract
In the current industrial context, marked by technological innovations, where adaptability and efficiency requirements become determining factors of the extended automation process, the improvement of production systems relies on selecting an optimal control method. This article provides a comparative analysis of two complex conceptual frameworks implemented in industrial process control: artificial intelligence (AI) and intelligent control. By presenting the functional foundations of each approach, the study highlights characteristics such as performance in environments with variable or uncertain behavior, implementation complexity, operational flexibility, reliability, and the volume of data required. The paper highlights the constraints and benefits of each method, through a comparative report based on specific performance parameters. The results indicate that intelligent control stands out in terms of efficiency and robustness in standardized applications with precise requirements, whereas AI, due to machine learning algorithms, delivers superior performance in dynamic and complex environments. In line with the analysis of the specific characteristics of the industrial process, the article provides a technical argument for determining the optimized control method.

Keywords
artificial intelligence, intelligent automation, control systems, real-time control, programmable controllers

1. Introduction

In industrial context, reducing breakdown time, energy consumption, waste and cost cut down have become determining factors in production processes efficiency [1].

Main challenges of engineering regarding processes are command and control systems development, creating innovative products, integrated processes, operations multifunctionality, standardization, extension planning for sensors, structural transformation of equipment, company growth strategy, supply chain organization, operational management, flexibility optimization [2].

Analysis of large amounts of data, in real time, regarding to predictability, with the purpose of improving control models and methods, offer companies the opportunity to optimize processes and grow productivity.

Industrial processes with intelligent control use modern technologies for data processing, optimization and collection. The purpose of using these technologies is to increase the quality, safety and efficiency of manufacturing operations. Process performance is based on advanced measurement, monitoring and analysis tools, integrated into automation systems. Implementing an automation system facilitates efficient communication and coordination between the various elements of a complex system. At the same time, the use of industrial monitoring systems and communication technology facilitates the fluid interaction between equipment and industrial processes.

On the other hand, the use of artificial intelligence in process control is becoming an important component in design and efficiency of equipment and processes. As processing speeds increase, system developer’s hope, using artificial intelligence (AI), to create smarter systems that can anticipate changes and bring further process improvements.

The concept of artificial intelligence consists of: autonomous organization, operational independence, self-management, decision-making skills, self-diagnosis.

2. Problem Description

2.1. Intelligent process control

In the process industry, established control and automation technologies have been developed and optimized over time to ensure the safe and efficient operation of equipment. These technologies focus on the use of automatic command and control elements to verify, analyze and interpret variables such as pressure, liquid level, temperature or flow.

In this field, the Programmable Logic Controller (PLC) is one of the most widely used tools. These are programmable, robust industrial computers that receive information from sensors and other measuring equipment, in the form of digital, analog or communication inputs. Data processing is carried out according to a set of rules developed from well-defined mathematical models. After applying these rules to the input data, output data is formed, which initiates actions on the controlled elements.

SCADA (Supervisory Control and Data Acquisition) is another key element of industrial processes. This advanced remote monitoring and control system is used primarily in complex projects, such as wastewater treatment plants, oil networks, or energy distribution systems. SCADA allows operators to monitor information about equipment performance, collect and analyze data in real time, and respond quickly to unforeseen events.

Another important part of intelligent process control is represented by the elements that acquire data from the process to the PLC. These elements are depicted by sensors or measuring devices that transmit analog, digital and receive data through standard communication protocols, ensuring the reliability and robustness of the system; as can see in Figure 1.

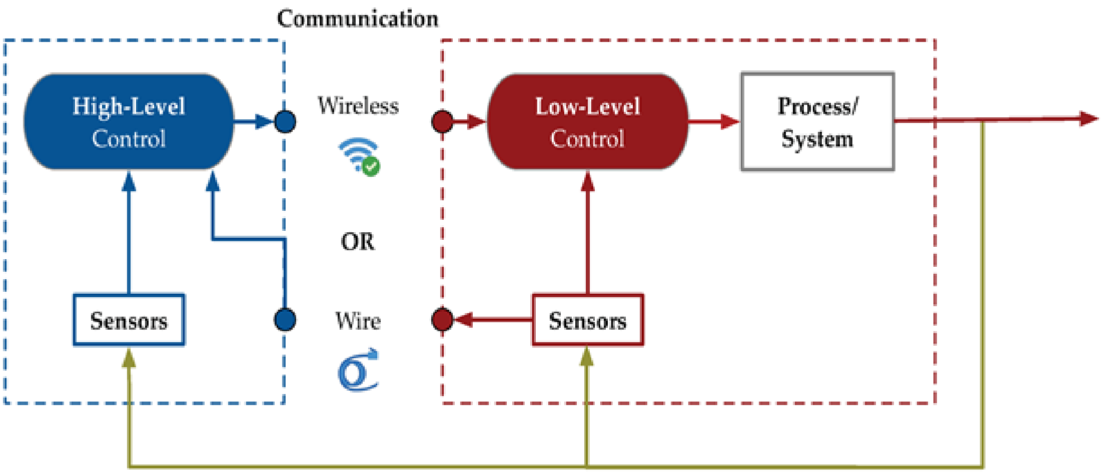

Fig. 1. Anatomy of an archetypal industrial control system. Hierarchical architecture

2.2. Artificial Intelligence (AI) in process control

Artificial Intelligence in industrial process control means the implementation of machine learning techniques, optimization algorithms and other modern technologies. This involves connecting AI mechanisms in the control system, optimization and monitoring of process data, which are decisive in a progressive industry. The flexible and intelligent solutions with which AI can substitute or adapt conventional technologies, such as control developed using classical algorithms or fuzzy control structures, offer an innovative perspective in the industrial field.

AI is enhancing process manufacturing by combining machine learning with first-principles methods for improved design, control, and safety. Challenges remain in data integration and system adaptability, suggested in Figure 2.

Artificial Intelligence (AI) can be classified into four main types based on their functionalities and capabilities. These four types are: Reactive AI systems (R-AI), Limited Memory AI systems, (LM-AI), Theory of Mind AI systems (ToM-AI), and Self-Aware AI systems (SA-AI).

Systems (R-AI) are the basic type of artificial intelligence (AI). They are designed to respond to specific inputs with predefined outputs without any memory or ability to learn from past experiences. This means that systems (R-AI) do not store information about previous interactions and cannot use previous data to influence future decisions. Systems (R-AI) are reliable in performing tasks because they will react in the same way to the same situation every time. They are created for specific purposes and cannot perform tasks other than those for which they are programmed, similar to the tasks of programmable controllers (PLC).

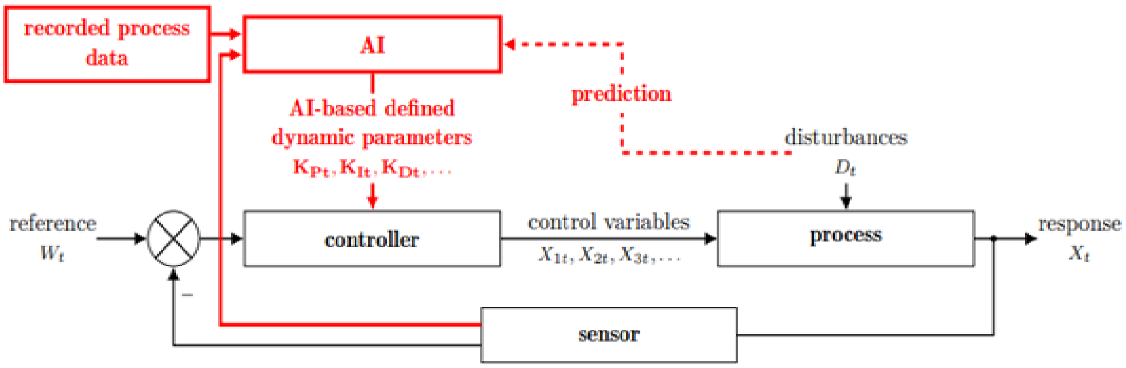

Fig. 2 Process control based on online and adaptive AI-based parameter set

Systems (LM-AI) are that type of artificial intelligence that is designed to work with limited memory values, allowing it to make effective decisions and perform tasks without requiring extensive computing resources. Systems (LM-AI) have short-term memory that allows them to temporarily store the experiences gained and act on them.

Systems (R-AI) and Systems (LM-AI) exist and are used in everyday life.

Systems (ToM-AI) are a type of AI that involves the ability to think about people's abstract mental states. Theory of mind is a state of cognitive understanding that involves emotions. Systems (ToM-AI) is not yet fully developed, although there is a lot of research in this area, so we can only expect results in the distant future.

Systems (SA-AI) refers to an intelligent system that possesses consciousness and the ability to perceive its own existence. Unlike traditional AI, which is limited to executing predefined tasks, systems (SA-AI) are aware of its actions, surroundings and even its own state. The idea that AI systems can become so intelligent that they have self-awareness is plausible. It is quite possible that super-intelligent systems that have a developed consciousness, just like humans, will be created in the not-too-distant future.

Systems (ToM-AI) and Systems (SA-AI) are today known at the theoretical level; these could be built in the future.

3. Methods Used

Intelligent control vs. Artificial intelligence

In the industrial environment, the emphasis has been on increasing the level of performance in order to ensure competitiveness and response to market trends. Whether we are discussing the modernization of a process or the design of a piece of equipment, a clear direction will be assessed and established on the objectives and requirements in order to develop an efficient and balanced solution.

The following characteristics are presented below that differentiate intelligent control from artificial intelligence (Table 1).

Although both proposed models aim to reduce operational costs, the intelligent control model will achieve this objective following the evaluation carried out independent by the system, and will be at a constant level until the next evaluation. The AI system will analyze at each stage, in real time, the possible optimizations, and will apply them, without the need for external evaluation.

Regarding the type of tasks that the system executes, the traditional control method can perform predefined tasks that do not undergo major changes over time, and their result remains constant during processing. On the other hand, having high potential artificial intelligence is capable of general tasks whose objectives can change over time, by applying self-organizing tools, adaptable to the complexity of the requirements [3].

Table 1. Intelligent Control (PLC) vs Artificial Intelligence (R-AI, LM-AI)

Intelligent Control vs	Artificial Intelligence
Reducing operational costs	Reducing operational costs
Specific tasks	General tasks
Real time analysis of a defined dataset	Real time analysis of a big volume of data
Repetitive actions that require the same result every time	Repetitive actions with dynamic response
Manual parameter modeling	Automatic parameter modeling
Corrective maintenance of equipment	Predictive maintenance of equipment
Control based on mathematical models	Control based on automatic learning algorithm
Fragmented approach	Complete and integrated approach
Standardization	Variability

The development of applications and their use in various fields have led to a rapid technological advancement of sensors and networks, which now produce large amounts of data. For the analysis and centralized control of process variables, the following steps are required: collection, processing, storage and monitoring of data resulting from the different stages of processing. Data management in a classic system is done using databases that are defined according to the monitored process, changes or expansion requiring manual intervention on the acquisition system. The AI model allows the storage of complex and large data, which is self-adapted by specific instrumentation.

Regarding the analysis of this data in industrial control systems, the same result is desired after monitoring the variables, while in the integration of Artificial Intelligence, its modification is desired based on previous situations, the latter having a decision-making factor [3].

Starting from this decision-making factor, in the case of AI, once the entire system has been analyzed, it dynamically modifies the parameters set for the system to obtain the most correct and realistic result. This is not accepted in a system without artificial intelligence, where the parameterization is done when defining the process model and can only be modified manually following human expertise [2].

Predictive maintenance is based on the data collected from the process and the state of the process at the time of data collection. Having the power to process a large volume of data and states of an element in the process, including self-diagnostic data from process instrumentation, it prevents defects, minimizes risks associated with processes and reduces losses of energy, material or time. While in automated control systems, graphical interfaces help operators visualize the status of equipment in real time and identify problems, through alarms and notifications, thus resulting in corrective maintenance on devices. The way the actuators are controlled differs in the two models. The classical method is carried out with mathematical models based on the causes and effects in the system, ensuring the stability of a process. These are necessary for the implementation and development of efficient control systems, because they describe and outline their behavior based on precise mathematical calculations [4]. In contrast, AI integrates decision-based control by automated learning algorithms. Applications for streamlining control systems and improving performance are developed from previous data, to anticipate process changes and to adjust parameters automatically.

In a fragmentary approach, system analysis is done individually on each component, without emphasizing the interdependent and complex relationships between them. Starting from the idea that each subsystem can be analyzed separately, solutions or problems are treated in isolation [5]. Stated differently, resolution focuses on a single functional or technical aspect, without taking into account the influence of other factors. The approach does not give importance to the interactions and complex connections that exist between the components of a system. It does not consider long-term consequences but offers solutions that are effective in the short term.

In the context of process engineering with artificial intelligence application, the system is built on an integrated and complete approach, which involves the overall monitoring of the project and its components [2]. Thus, the optimization does not focus on a single aspect but on the entire process cycle, starting with data acquisition, preprocessing, predictive modeling, post-processing, and up to implementation in production. In such an approach, in order to obtain viable, sustainable and long-term efficient solutions, relationships with the whole are the relevant aspects that determine making a decision or solving a problem. By analyzing from multiple perspectives and several factors, incomplete or partial solutions can be avoided.

Standardization, often found in automatic process control, contains rules, procedures and steps, used to obtain controllable, predictable and replicable results. The processes are characterized as being organized, methodical and structured, which allows certain activities to be carried out in an efficient way, reducing errors and instability [5]. The activities are, in a logical way, sequenced and planned, to allow the constant control and monitoring of the process, to ensure that it respects the established objectives. In a context where processes and methods change over time, and actions adapt to ensure the functionality of the entire system, AI adopts variability. To solve a problem, AI instead of following a predefined procedure, analyzes frequent errors and states, identifies different characteristics and adapts the solution to the current state of the system.

4. Discussions

Implementing artificial intelligence in process control comes with challenges. Current infrastructure is one of the most common impediments to AI integration. Most industrial processes are complex, and merging AI with traditional technologies is often not possible, which often leads to equipment replacement and considerable software modification. It should also be taken into account that in order to prevent malfunctions in the command-and-control process, the AI models must be very well trained and tested [3].

Although the AI will be responsible for the entire decision-making process and work parameters, the function of the PLC and the classic method of controlling a motor, for example, will remain the PLC's, but the AI will make the decision and give the start signal.

5. Conclusion

In conclusion, traditional automated industrial process control, such as SCADA, PLCs and process instrumentation, controls a fixed, repeatable process with stable results. These technologies help develop devices capable of executing complex commands to ensure quality and safety standards.

On the other hand, artificial intelligence is focused on developing systems capable of performing advanced decision-making tasks that can be executed without human intervention, bringing benefits to industrial process control by improving the quality, efficiency, and safety of operations. AI automates many tasks but cannot replace human creativity, problem-solving, and strategic decision-making entirely. Instead, it enhances workforce efficiency. Although AI comes with these advantages, its implementation requires accumulating a large volume of data for training the model that underlies a process, but it is a necessary subassembly in industrial process control and automation.

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