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Industry 5.0 in Industrial and Academic Applications

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Abstract**:** ***Technology 5.0 combines analytical thinking algorithms with leading technologies such as the Internet of Things, smart factory, cobots and artificial intelligence. With the growth of manufacturing, the digitization process is the only way to ensure further growth opportunities in the future. The article presents the most important features of technology 5.0, according to the authors. They found several examples in the literature related to artificial intelligence. Two extreme examples are then presented. An academic testbed using an artificial intelligence module built at the Maritime University of Gdynia, Faculty of Electrical Engineering. We propose a testbed configuration based on image recognition based on the S7-1500 controller and Intel RealSense camera. The first example shows how to configure the Linux environment and Phyton language needed for teaching artificial intelligence. Steps for implementing the learned AI model into a Siemens Neutral Processing Unit (NPU) module are given. This provides a glimpse of academic solutions. Recognized as the theoretical methods needed for artificial intelligence module research. The second example provides general information about the application of 5.0 technology at GPEC (Thermal Energy Company - Gdansk). It provides a broader view of the application of 5.0 technology in industry. The results chapter compares the proposed two solutions based on the described technology, showing the potential of both solutions, which are closely related to artificial intelligence algorithms. According to the authors, they are based on image recognition based on a classification algorithm and machine learning techniques. The authors propose a prototype of the test bed needed for Internet 5.0 research in laboratory conditions while giving general applications in industrial conditions.***

Keywords: Artificial Intelligence, Decision Tree, Machine Learning, Neural Networks, Programmable Logic Controllers

I. INTRODUCTION

Idustry 5.0 is supposed to be about transforming ordinary machines into self-learning and human-safe devices to improve efficiency and increase productivity "This broader goal is made up of three basic elements: human-centricity, sustainability and resilience." [1]. The goal of the technology is to build an intelligent manufacturing platform for IT applications and industrial networks. The requirements of the new industrial revolution are real-time data monitoring, product localization and production control. Meeting the above goals is possible by introducing artificial intelligence to optimize production and collaborate with humans, which requires awareness of ethical, legal and cyber security aspects. The concept of Industry 5.0 introduces a revolution in industry while maintaining compliance with previously accepted design standards. "The fifth industrial revolution will emerge when its three main components - smart devices, smart systems and smart automation - fully connect to the physical world in collaboration with human intelligence." [2]

Neural networks have become a popular tool for problem solving. The use and construction has been undertaken by the IEEE (Institute of Electrical and Electronics Engineers). Modeled after the human brain, they are mathematical, software or hardware structures. The speed of the human brain is estimated at 1018 operations per second, where the world's fastest computer, Fugaku, built in 2020, achieves 4.42*1017 operations per second. The networks are based on a simplified model of the brain consisting of information-processing elements called neurons. Each neuron has interconnections with parameters, which are called weights. The weights can be modified during the learning process, and the topology of the connections determines the performance of the network. The most important feature of a neural network is the ability to process information in parallel and self-learning - whereby the network analyzes the input data and makes a categorization decision [3]. For example, the authors [4], [5] provide details of electronic components useful for designing advanced information infrastructures, including implementations of circuits describing feedback logic for use improving intelligent manufacturing systems. They propose Industry 5.0, which can democratize the co-production of knowledge with Big Data, based on the new concept of symmetric innovation.

The article [6] describes how AI PLC and NPU have been used for industrial control. Our article gives the common part between the widespread use of 5.0 technology in industry and a research station at a Gdynia University Maritime with an AI module.

II. CONCEPT AND TASK

The development of Industry 5.0 is based on the following four tasks:

Interoperability - cooperation of machines, tools and computers in one network, one same communication system. Researchers are working on the topic of 6G network generation [7], [8] and [9].

Fragmented decision-making - systems that can perform several tasks independently, e.g., cobots cooperate.

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Transparency of information - the ability of computer systems equipped with sensors to virtualize versions of real machines, the same part is virtual as in the case of 3D systems.

Technical support - computers along with artificial intelligence support employees in strategy, decision-making and work. This is as important as blochain. The increase in the distributed number of networked devices requires the development of remote management methods. One such method could be blockchain technology, which enables secure peer-to-peer connections.

Regardless of the rate at which some industries are adopting technologies, some will grow exponentially, involving a greater commitment to deploying IoT or cyber-physical systems.

III. NEURAL PROCESSING UNIT FOR PLC

Siemens offers the S7-1500 TM Neural Processing Unit (NPU) module containing an integrated AI chip that is a dedicated module for the S7-1500 and ET 200MP system. The laboratory for programmable controllers received funding under a grant from the Ministry of Education and Science with funds from the state budget under the "Student Scientific Circles Create Innovations" program, thanks to which a prototype of an Industry 5.0 network was made based on the requirements outlined in the section "Introducing Industry 5.0 technology." Human expertise can be stored in the module for use in identifying an image using a neural network. It enables direct integration of new applications based on artificial intelligence into the SIMATIC system. The module derives its knowledge from a pre-learned network to be inserted into the SD card connector. In addition, it is equipped with a USB 3.1 interface and a Gigabit Ethernet port for connecting a camera. The data processed by the module can be supplied from external sensors or a program in the controller. The result of the processing is evaluated by the processor program and is made available for use in the PLC program by means of an input image. In addition to NPUs, there are deep neural networks called DNNs (Deep Neural Networks). DNN solutions require server resources with high computing power, such as those based on GPUs (Graphics Processing Units). In this case, NPU modules are more compact and energy-efficient, however, this translates into reduced bit precision for the representation of numbers. The image processing part of the NPU module is based on Intel's Movidius Myriad X VPU technology with a base frequency of 700 MHz.

The chip contains 16 low-power programmable SHAVE (Streaming Hybrid Architecture Vector Engine) cores and is equipped with a dedicated hardware accelerator for processing deep neural network structures proposed in figure 1. In the second figure (fig.2), the realization of the proposed workstation from scheme 1.

Process of creating a neural network can be divided into several main tasks:

- preparation of training data - sets of categorized photos,
- data balancing - selection of photos taken under the same conditions for a given category,
- generating the neural network using the TensorFlow library and training the model.

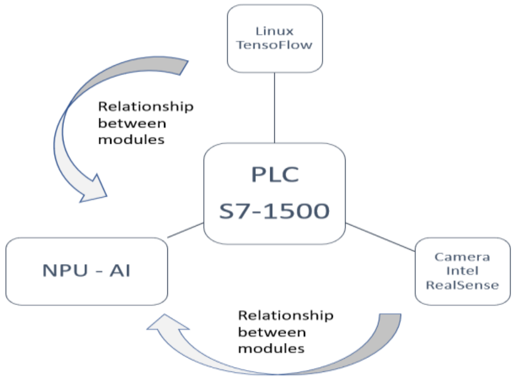

Fig. 1. Basic diagram with modules and the relationship between them in the proposed lab bench.

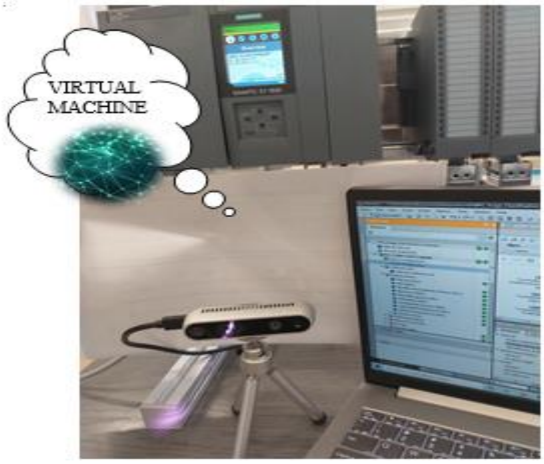

Fig. 2. Propose solutions for laboratory in University in Gdynia. PLC is S7-1500, Module NPU, camera Intel and TIA Portal v16.0, virtual machine Linux with OpenVINO.

Process of learning with a teacher involves assigning to each object a corresponding category or action containing both input and output data. The next step is feature extraction that's means extraction of the parameters that characterize them which will allow better categorization. This is followed by machine learning - algorithms that result is cause-effect relationship on how task should be solved. Finally, a file is generated, which save as a Python script. Convert the previously created file to BLOB (Binary Large Object) format using the Open VINO library (Figure 3). Finally, the model write to an SD card before placing in NPU module slot card.

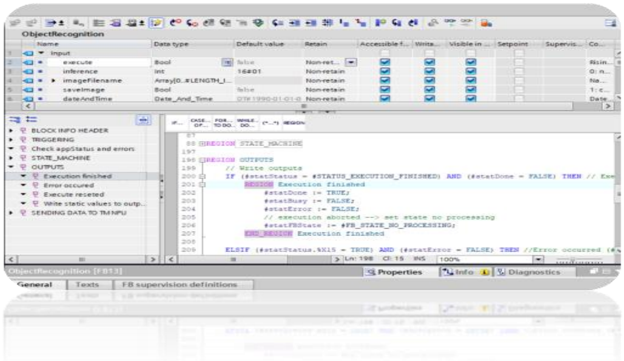

Fig.3 Example program in TIA Portal implement on PLC.

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In TIA (Totally Integrated Automation) project's hardware configuration window, the signal source must be specified, but the IP address for the Ethernet option is stored in a file located on the module's SD card, structured as follows:

- config/network. conf - IP address for the NPU module,
- res/npu_app. conf - AI configuration file describing available models,
- res/model. blob - neural network model (there can be multiple models in the directory),
- scripts/main.py - definition of values according to the neural network model from the res directory.

The camera recognizes the image and verifies that it is correct. Currently, we only get the information that the object (box) is recognized. Recognition is the result of learning in a virtual machine based on AI training models this is implemented into the NPU module and a "yes" message is produced in the controller indicating that the box has been recognized nothing more (Fig.3). We want to combine this information with the operation of the robot, but this is only in the next research. Describe station can recognize for algorithm detected object, we have plane recognize box whose can change position for example like cobot.

IV. OPTIMIZATION OF HEAT SUPPLY COSTS 5 TECHNOLOGY IN INDUSTRY

GPEC is implementing the project "*Development of an innovative system to support efficient management of the heat network*" aimed at creating a system for automatic and optimal control of the operation of the district heating network. The company is investing in the latest technologies and upgrading facilities to reduce the cost of operating the district heating network. A significant cost component for the district heating company is electricity. Energy consumption affects the cost of providing heat which is directly related to the tariff offered to consumers. The district heating network consists of pressure boosting stations and chambers, and each of these facilities is connected to a telemetry network. The pumping stations supply heat based on information from critical nodes by regulating the dispatchable pressure. Booster stations are a key component of the system consisting of a system of pumps, valves and a set of sensors for pressure control. Due to the large differences in altitude found in the city of Gdansk, the pumping stations are equipped with high-capacity pumps, and the process itself is required to ensure adequate pressure at the exit to the nodes and the return to the CHP plant. The project is divided into several modules consisting of industrial research. Tasks include the introduction of expert rules in the software of the programmable controller of the booster station and the detection of anomalies in the operation of district heating nodes based on machine learning methods.

V. RESULTS: ANALYSED BOTH TECHNOLOGY

The tabular description contains common features of the analysed technology for the two examples does not include information on, for example, blockchain, data fragmentation or 5G technology. In both examples, these issues were not legitimate, needed.

Table I. The Compare Both Example Industrial and Academic Application

Technology	Example	
	Industrial	***Academic station***
IoT	Telemetry system based on devices equipped with GSM connectivity	None, but there is a possibility of expansion
Machine Learning	Decision tree – proposed LightGBM / XGBoost	Neural network implemented in S7-1500 TM NPU
Cybersecurity	Compatibility with IEC 62443	None
Communication protocols	Modbus TCP/RTU, Profinet, Profibus, M-Bus, MQTT, SMTP	Profinet including S7-connection
Analysis software	Termis, Python	Python
Period time	Average 1 minute - implemented via OPC server	Real time – RealSense depth camera

The lab bench provides a good base for learning new solutions, and the TM NPU itself allows for various implementation examples. Inspiration can be taken directly from Siemens' "Artificial Intelligence in Industry" page, where selected cases are described [10].

The industrial example is significantly expanded compared to the academic one. This is due to the span of the district heating network and the variety of equipment used at GPEC - the telemetry network is about 12,000 points. Electricity meters or heat meters have been equipped with the M-Bus (Meter-Bus) protocol, which allows direct reading of device registers without pulse processing. The bus also gives the possibility of remote diagnostics, which is significantly limited when using digital signals.

VI. CONCLUSIONS

Industry 5.0 is expected to enable real-time access to information, which will translate into control and resource planning, while the use of machine learning techniques will support humans in performing repetitive tasks. The two extreme cases given in the text have in common - 5.0 technology, which can be developed in terms of AI algorithms used (in this case, an image detection algorithm) and development in terms of cyber security. Both the presented position of the industrial complex and the academic complex are no longer purely academic considerations, they interpenetrate each other due to the potential of the components used. Both Siemens NPU can be introduced into complex industrial systems and typically computational academic systems. The manufacturer's proposed solution, which is implemented in the laboratory, will enable work related to the AI module working according to image classification, and in the future algorithms based on image detection algorithms can be considered. In accordance with the requirements of the European Union, and more specifically with the AIDA (Artificial Intelligence in a Digital Age) commission, the impact of the artificial intelligence factor on social behavior will be studied. In addition, work is currently underway on the legal aspect.

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In the report that the AIDA commission presented in 2021, one can read "Highlights that AI can be a game changer for EU industry competitiveness and has the potential to increase productivity, accelerate innovation, improve production processes and help monitor the resilience of European supply chains." [3]. Undoubtedly, the technological leap at the turn of the 20th century enables the introduction of, among other things, artificial intelligence, which, according to the EU commission, will be more widely implemented in 2040.

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