Using Cognitive Services within CPS/SCADA Systems Federations - Concepts, Research Areas and Challenges

Andrei Scurtu
Department of Automation
Technical University of
Cluj-Napoca, Romania
scurtuandrei@rocketmail.com,

Cătălin Dehelean
Department of Specialized Foreign Languages
"Babes-Bolyai" University
Cluj-Napoca, Romania
gravedale01@yahoo.com

Szilárd Enyedi
Department of Automation
Technical University of
Cluj-Napoca, Romania
Szilard.Enyedi@aut.utcluj.ro

Liviu Miclea
Department of Automation
Technical University of
Cluj-Napoca, Romania
Liviu.Miclea@aut.utcluj.ro

***Abstract*—Artificial intelligence has entered all the underpinnings of modern science to such an extent that any field with a pretense of progress is bound to make room for this chapter. It is a cornerstone of modern applied science. This article will circumscribe a few fundamental aspects which characterize the AI universe, highlighting the important features thereof. The field of applications for CPS/SCADA has been significantly boosted by the integration of AI within its most basic structures. An important feature of the development and integration of AI in the modern world of software is brought about by the providers of AI services which allow for their integration, with ease, in the SCADA application as well as in many other applications. In the last section of the article, we discuss aspects related to the most important suppliers of this type of service, those belonging to the present-day.**

Keywords—CPS; SCADA Federation; Internet of things (IoT); Edge Computing; Custom Vision Services and API; Artificial Intelligence; Machine Learning; Image classification model.

I. INTRODUCTION

Human involvement in the evolution of intelligent systems has been and still is the main leverage these systems have got. These systems have, thus, played only a passive role, receiving their evolutionary characteristics from the specialists in this field. Intelligent systems, in the same manner as mathematics, have moved on from a historical stage of development to another one due to the creativity of the specialists who worked on them, these systems having no status of partial or complete independence from their authors.

Artificial intelligence is the main mechanism that allows for the independent evolution of intelligent systems. The instruments which these systems can rely on, pertain to recursive levers, whereby the evolution is being tracked. Human systems have, as an underlying principle, data analysis, the extraction of the principles, features which also define their building of higher profiles which enable raising the bar in the analysis. Data synthesis and the creation of the abstract higher-level structures have been ways to move from one stage of development to another. For example, the generalization of the principles and features of the Euclidean geometry has allowed for the creation of a superior level called non-Euclidean geometry to act as an instrument of evolution. This process of evolution has been carried out using the self-analysis of the existing system [2] by creating a higher-order profile whereby one can move on to the next stage. One could call this process the abstraction stage which is formed as a result of the observation of some characteristics of the existent system and the development of these characteristics.

Artificial intelligence has made its way into the life of each one of us via the tools which we use in our daily lives. The smartphones, the gadgets in the supermarkets, the computer, the tablet PCs, the smart TV sets are all equipped with a level of artificial intelligence specific to the purpose they were designed for. Amazon Echo, Apple Siri, Google translate adapt their processing algorithms according to the data package and offer adaptive evolutional solutions. The applications offered by the various developers adapt their behavior to the history of our user habits, thus offering us an increasing amount of comfort while, at the same time, suggesting solutions that may optimize our activity. On an industrial scale, the creative potential is even higher.

To draw a defining sketch of Artificial intelligence, it is necessary to review several mechanisms that form the main firing pins of the self-evolving systems. A mechanism which we shall review is machine learning. [1]

II. CONCEPTS

A. *Machine Learning*

Machine learning is a procedural system that uses mathematical instruments of data analysis. We would like to point out that the concept of data analysis covers any information which may describe qualitative or quantitative defining features of the analyzed system.

Machine learning may identify useful relational (or correlational) patterns between different agents and data. How machine learning adapts is similar to how people learn.

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The objective of the learning process is to provide techniques, algorithms for solving future situations.

The first procedure employed by machine learning is object recognition. The technique used for object recognition is based on image analysis. Each object has a characteristic structure that defines it. The washing machine, the umbrella, the radio, the bus, etc., all have a unique structural characteristic, which allows for their recognition. [3] Each type of object consists of hundreds of images that reflect specific features, seen from different angles.

By analyzing the various images, the machine learning algorithms can identify certain objects by identifying the patterns.

B. *Predictability*

Predictability is a markedly common feature of Machine Learning. Predictability is a form of estimating future behavior based on the historical data of the entity. Predictability is often used for estimating human behavior, using performing an analysis of the existing data to determine patterns. For example, by analyzing historical data, one may estimate the behavior of the consumer. As such, one may estimate which products, categories of products somebody will acquire in the next period.[4] A first application that identifies just such patterns allows the sellers to create product profiles as well as to create promotional offers to attract customers.

The use of machine learning with a predictive purpose is sometimes referred to as predictive modeling or Predictive Analysis. The use of machine learning with a predictive purpose is so frequent that Predictive Analysis is often used as a synonym for Machine learning. [2]

Another paradigm often used to reflect the synonymy of Machine Learning and Predictive Analysis is outlined in a different concept called Uncertainty Reduction. Machine learning does not offer absolute certainty, instead, it provides useful information with a certain degree of realization. We know that a certain customer is doing his shopping, with a high degree of repeatability, from a certain store, we know the percentage of repeatability in the acquisition of certain products, made by a certain manufacturer, but this only allows for estimates such as there is a 70% chance that client X in a test sample may acquire type Y bread, 10% chance that one may buy Scottish whiskey, etc. These probabilistic ratios allow for the creation of offers which may increase the chances of attracting a client, for example, an intelligent supplier will increase the range of bread with loaves offered by manufacturer Y, rather than widen his range of Scottish whiskey which is nothing more than an occasional acquisition of just 10%.

C. *Predictive model*

A predictive model is a result generated by the processual mechanisms of Machine Learning. In other words, the predictive model is the end product of Machine Learning. There is a very wide range of types of predictive models, beginning with the mathematical models used the basis of generating a predictive model.

In countries with developed banking systems, credit scoring is used as a predictive model generated based on the profile of the person soliciting a credit. The lifestyle of a person allows for the generation of predictive diagrams which may offer an estimative basis of the reimbursement of the credit on the timescale. [5]

Another example of using Machine learning is given by target marketing. Starting with the personal information of a person, such as age, gender, income, data generated by the web browsing, the personal history of acquisitions, location and other determining factors, it may be approximated with a high degree of accuracy, if the person is interested or not in a certain product.

An important example regards the preventive medical system, in which Machine Learning plays an important role. Evidently, until recently, the mainstream medical system manifested only a reactive feature, which meant that the preventive aspect took on a secondary position, a fact which has not radically changed. The patient asks for help at the moment the organism exhibits behavior which requires attention, and the doctor intervenes, in this case, trying to provide a remedy for the affected functionalities.[7] Nonetheless, the modern tendency is focused on using predictive models; it has, thus, been noticed that Machine Learning may optimize costs, using previsions, thus, reducing the patients' costs. To generate these predictive models, data from the patients' health records are used.

D. *Deep learning*

In the 1950s, the concept of the artificial neuron was one of the first concepts which have marked the field of IT. However, it would be three decades later that these concepts came to life. The debut concept in the middle of the 1980s was not the neuron, as a concept in its own right, but the artificial neural network. [6]

Neural networks are nothing more than a set of algorithms meant to detect and recognize patterns. We may grasp this concept from at least two different points of view – the structural point of view and the functional point of view. Structurally speaking, a set of interconnected neurons form a neural network. It is a translation of the image created based on the analogy with the human brain. Functionally speaking, we may define the neural network as a system composed of any number of interconnected elements whose role it is to solve a problem. Another rather important aspect is the ability of the neural networks to adapt so that they optimize their paradigms of analysis and targeted problem solving, using a system that is similar to that of human learning.

Deep Learning represents the last stage in the development of the neural networks. In theory, the evolution of the neural systems from a level to another is an infinite process; however, complexity increase is a process of deepening the learning, so that, it can be considered that after 2-3 levels of development of the networks, we have a deep learning level. [1]

The most complex models of neural networks existing at present are the ones developed by Google, called DeepMind and they number millions of neurons connected on the surface of several tens of levels.

III. RESEARCH AREAS – CPS, SCADA AND AI

A. *Cyber-Physical Systems*

Cyber-Physical Systems (CPS) are the epitome of large-scale hardware-software co-design and symbiosis. Beside smart manufacturing, smart grids and other traditional, but evolving industries, we see emerging technologies like

networked autonomous cars and community-enhanced personal robots which will also benefit from new integrated hardware and software, where a part of the decision making will be shifted towards the cloud. The remote, low-powered and loosely connected edge nodes of these CPSs will ask for sensor fusion and efficient, resource-frugal, pre-trained neural networks.

B. *Supervisory Control and Data Acquisition*

SCADA is increasingly based on the Internet of Things (IoT). SCADA systems benefit from the development of artificial intelligence, just like any other intelligent equipment which is meant to possess cognitive evolutional abilities. The implementation of artificial intelligence components gives rise to a new problem specific to the development of every system, i.e. the effort necessary to attain it. The effort is translated into several attributes such as the costs of the acquisition of the necessary equipment, hardware, and software, as well as the human effort put into system design and implementation. Since this cycle is repeated with the development of every SCADA system, fitted with AI components, a common principle may be used, namely the creation of reusable specialized components. These components may have a generic character so that it may offer a possibility to save and optimize the effort to integrate the AI systems into intelligent systems. [7]

An important advantage of these generic services is the uniform development of the components, so that every user may enjoy the same number of AI attributes, as well as consistent quality. On the other hand, the uniformization of an offer of this type allows for the updating, at a higher rate, of all the systems which use AI components, not requiring a separate, unitary, update, done only when it is decided that a system needs to be updated. [8]

C. *Autonomous vehicles*

Although not closely related to SCADA, self-driving vehicles and robots are some of the best use cases for AI. Besides self-driving road-legal vehicles, which already exist and transport people or cargo, autonomous land or aerial drones are also currently employed, albeit in simple environments, to check communication lines or long-distance supply pipes, and their role will only increase in the future, not to mention the knowledge they – and we – will gather from their learning, feedback, hive mind and adaptability.

D. *Cognitive services*

Like most of the cloud services suppliers, Microsoft has become a cloud services supplier that has integrated AI (Artificial Intelligence) functionalities its service packages. Cognitive services represent one of the largest AI packages offered on the market which includes Machine Learning and Machine Vision.

Most of the modules integrated into cognitive services are capable to understand the Microsoft natural languages (NLU) and chatbot.

Cognitive services allow for the development of these agents using a few attributes, such as – scalability, which supports expansion, intelligent recommendations offer ad-hoc translation processes, the use of Machine Vision for profile recognition. [9]

There are five important categories of cognitive services:

- computer vision – which extracts important information from images,
- content moderator – allows for the limitation of the access to the content such as text or image with specific semantics,
- emotions – allows for the analysis of facial features and the identification of certain states,
- face – allows for the identification of the face and the analysis thereof and its comparative features
- video – allows for the video content analysis and editing in software applications.

Microsoft – offers built-in functionalities in the guise of application programming interfaces, APIs. These AI agents are meant to help developers, making their work easier, reducing the implementation efforts and costs.

Microsoft sets forth a few cognitive services APIs:

- Vision APIs - Computer Vision, Face Recognition, Ink Recognizer;
- Speech APIs - Speaker Recognition, Speech to Text, Text to Speech;
- Language APIs - Text Analytics;
- Decision APIs - Anomaly Detector, Personalizer.

Google – is another supplier of cloud services and products with AI functionalities in their packs.

Products and services offered by them may be grouped in a few categories: [11]

- AI Hub;
- AI building blocks;
- AI Platform.

Google Cloud AI Hub offers enterprise-grade sharing capabilities including "out of the box" algorithms which allow for private hosting of AI content to favor the reuse and the collaboration between developers and internal users. [12]

AI building blocks provide instruments that allow software developers to add AI functionalities to their applications.

AI Platform provides a development environment that offers the AI software developers, the scientists in the field of data science and the data science engineers the ability to develop the projects from ideas to implementation in a fast and cost-effective manner.

Some of the cognitive services APIs offered by Google are:

- Vision AI – analyzes images in the cloud;
- Video AI – video analysis precise to frame level;
- Natural Language – multimedia and multilingual processing;
- Dialogflow – offers conversational experiences on devices and different platforms;
- Cloud Inference API – runs large-scale correlations between time modular data sets;
- Cloud AutoML – trains customized ML models.

Google offers TensorFlow, which is an open-source platform for Machine Learning.

It has a flexible, comprehensive ecosystem of instruments, libraries, and resources that allows the researchers to push the state of technology into ML and developers to easily build and develop Machine Learning applications.

The development of these services allows for the facile integration of some particularly complex functionalities in

SCADA applications, while, at the same time, allowing for the development of a new vision of the current SCADA model. The global tendency of AI is to penetrate all intelligent systems and to provide them with self-development capability as well as with independence from the human element.

Even if, during the past three or four decades, the evolution of the intelligent systems has reached a level far above the predictions of the previous centuries, the rhythm of the evolution is quite slow relative to the existing requirements. The only possibility to create an evolution on a massive scale is using self-educating the systems to create their rhythm of evolution, without the intervention of the human agent, perhaps with the supervision of the later.

To support this project of global development there has to be awareness and an opening towards the rapid integration of the AI systems into the SCADA systems, so that, the framework required for a self-sustained evolution may be created. [10]

IV. Challenges

The technological universe, both the software and the hardware, has made remarkable progress in the past 50 years, so that the rate of development has constantly accelerated until it has, currently, reached a volume of technologies that exceed the assimilation capacity of the average developers. If, until 10 years ago, a perseverant software developer could have been familiar with the technological progress, nowadays, a high level of learning ability is required, as well as a flexible program wherein 40% of the time is allocated to the study. The current technological landscape has allowed the debut of a new AI character, along with the top competitors of the associated products and services. If, for now, the cognitive services are a new and exciting chapter for the world of AI consumers, it is likely that in a short amount of time, new AI suppliers of a new range of this kind of products and services may arise. It is very difficult to anticipate the direction in which the technological universe is developing, due to a very wide spectrum of products featuring a highly competitive character. We are heading towards a future where the progress and the independence of the technological products will bear the hallmark of AI. The somewhat distant future will likely resemble the images depicted by movies such as Stargate SG1- Atlantis, and its famous replicators endowed with maximum levels of intelligence.

V. Conclusions

The paper presents the main notions regarding the using of cognitive services within the SCADA System Federation. Although the concept is decades old, today's societal and technological challenges, the slowdown of semiconductor development and traditional computational breakthroughs in general, the artificial cognitive platforms enabled, ironically, by the aforementioned traditional electronics and processing resources, sparked a new interest in cognitive technologies. Based on the presented ideas, a collaborative instrument for water management was developed, making the transition to Cyber-Physical Systems easier.

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