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A Summary of Future Trends in Automation Industrial Processes

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Abstract: *The importance of automation in the process industries has increased dramatically in recent years. In the highly industrialized countries, process automation serves to enhance product quality, master the whole range of products, improve process safety and plant availability, and efficiently utilize resources and lower emissions. In this paper we are going to study the process automation through bibliographic research, and to showcase its future trends.*

Keywords -*process automation, industrial automation, robotics, artificial intelligence, control systems*

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I. Introduction

The starting points in assessing the future needs for automation are, on the one hand, global development and economic trends, and, on the other, the way in which they are reflected in the development of society and the economy [1-5].

The importance of automation in the process industry has increased dramatically in recent years. It has become a force in the entire chemical, oil, gas and biotechnology industries. Innovative instrumentation systems now control complex processes, ensuring process reliability and safety, and provide a basis for advanced maintenance strategies. Incessant cost pressures in the chemical and bio industries leave no alternative to improved productivity. Companies need to take a holistic approach to quality, cost and time issues, and automation engineering will play a central role [4-5].

In this paper the industry trends that are shaping current automation requirements, as well as the future trends in process automation, are presented and discussed.

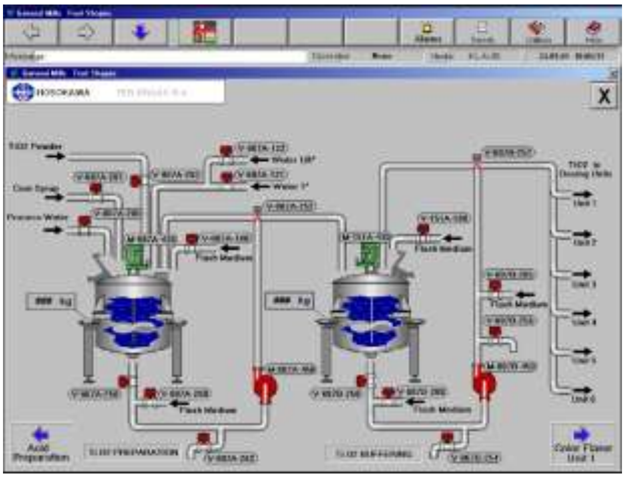

Figure 1: Mimic diagram (Hosokawa SCADA)

II. Background

A process automation or automation system (PAS) is used to automatically control a process such as chemical, oil refineries, paper and pulp factories. The PAS often uses a network to interconnect sensors, controllers, operator terminals and actuators. A PAS is often based on open standards in contrast to a DCS (distributed control system), which is traditionally proprietary. However in recent times the PAS is considered to be more associated with SCADA systems (Fig.1)[1-3].

In the absence of process automation, plant operators have to physically monitor performance values and the quality of outputs to determine the best settings on which to run the production equipment. Maintenance is carried out at set intervals. This generally results in operational inefficiency and unsafe operating conditions [4-5].

Process automation simplifies this with the help of sensors at thousands of spots around the plant that collect data on temperatures, pressures, flows and so on. The information is stored and analyzed on a computer and the entire plant and each piece of production equipment can be monitored on a large screen in a control room [2-5].

III. Future Trends

Automation is any technology that allows the automation of a process / work. Following are the future technological trends in process automation [5-16].

3.1. Modern Control Systems

Modern control systems are almost always implemented in a digital computer. In modern control the design of the control system is implemented by feedback of the state variables (Fig.2). Modern control offers the ability to use an Operational Performance Index (ADI) to make a system optimal in time response or energy use.

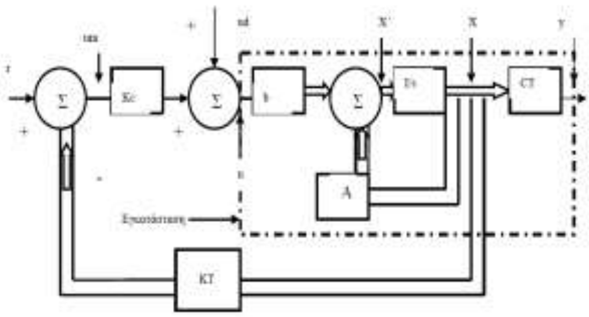

Figure 2:Modern Control System

3.2. Modern Control Systems

Optimal Control is used when minimizing a specific performance or cost criterion (time, energy) is required. Using this criterion or function, a suitable control rule is implemented that is implemented with a controller called the Linear Quadric Regulator (LQR)(Fig.3).

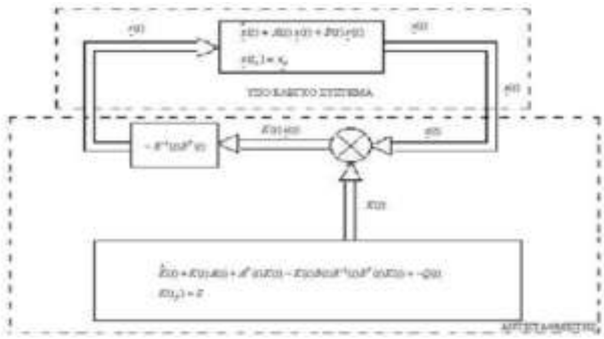

Figure 3: Optimal Linear Regulator

3.3. Fuzzy Control

A fuzzy control system is a control system based on fuzzy logic—a mathematical system that analyzes analog input values in terms of logical variables that take on continuous values between 0 and 1, in contrast to classical or digital logic, which operates on discrete values of either 1 or 0 (true or false, respectively)(Fig.4). Figure 5 shows a fuzzy PIC controller.

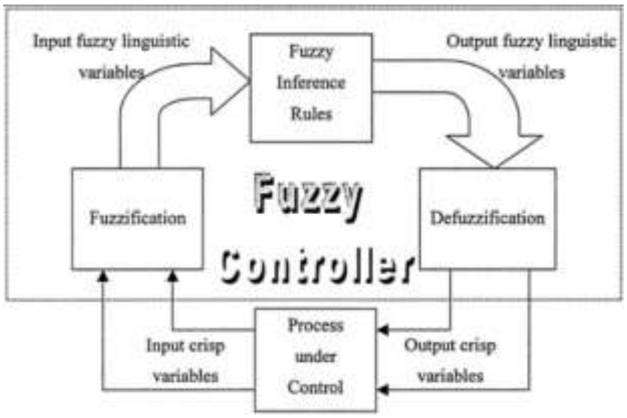

Figure 4: Structure of Fuzzy Controller

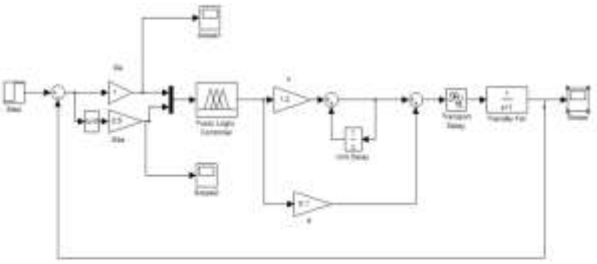

Figure 5: The Fuzzy PID Controller in Simulink

3.4. MACHINE LEARNING

Machine learning is a field of computer science that gives computer systems the ability to "learn" (i.e., progressively improve performance on a specific task) with data, without being explicitly programmed. Machine learning tasks are typically classified into two broad categories, depending on whether there is a learning "signal" or "feedback" available to a learning system (Fig.6):

I. Supervised learning: The computer is presented with example inputs and their desired outputs, given by a "teacher", and the goal is to learn a general rule that maps inputs to outputs. As special cases, the input signal can be only partially available, or restricted to special feedback:

- Semi-supervised learning: the computer is given only an incomplete training signal: a training set with some (often many) of the target outputs missing.
- Active learning: the computer can only obtain training labels for a limited set of instances (based on a budget), and also has to optimize its choice of objects to acquire labels for. When used interactively, these can be presented to the user for labeling.
- Reinforcement learning: training data (in form of rewards and punishments) is given only as feedback to the program's actions in a dynamic environment, such as driving a vehicle or playing a game against an opponent [5].

II. Unsupervised learning: No labels are given to the learning algorithm, leaving it on its own to find structure in its input. Unsupervised learning can be a goal in itself (discovering hidden patterns in data) or a means towards an end (feature learning).

Another categorization of machine learning tasks arises when one considers the desired output of a machine-learned system:

- In classification, inputs are divided into two or more classes, and the learner must produce a model that assigns unseen inputs to one or more (multi-label classification) of these classes. This is typically tackled in a supervised way. Spam filtering is an example of classification, where the inputs are email (or other) messages and the classes are "spam" and "not spam".
- In regression, also a supervised problem, the outputs are continuous rather than discrete.
- In clustering, a set of inputs is to be divided into groups. Unlike in classification, the groups are not known beforehand, making this typically an unsupervised task.
- Density estimation finds the distribution of inputs in some space.

- Dimensionality reduction simplifies inputs by mapping them into a lower-dimensional space. Topic modelling is a related problem, where a program is given a list of human language documents and is tasked to find out which documents cover similar topics.

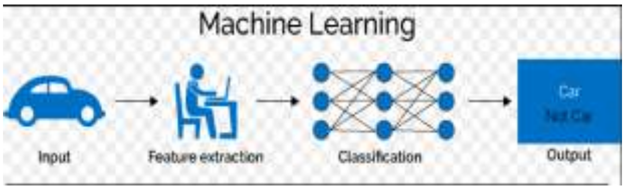

Figure 6: The Machine Learning context

3.5. NEURAL NETWORKS

Artificial neural networks (ANNs) or connectionist systems are computing systems vaguely inspired by the biological neural networks that constitute animal brains (Fig.7). Such systems "learn" (i.e. progressively improve performance on) tasks by considering examples, generally without task-specific programming. For example, in image recognition, they might learn to identify images that contain cats by analyzing example images that have been manually labeled as "cat" or "no cat" and using the results to identify cats in other images. They do this without any a priori knowledge about cats, e.g., that they have fur, tails, whiskers and cat-like faces. Instead, they evolve their own set of relevant characteristics from the learning material that they process.

An ANN is based on a collection of connected units or nodes called artificial neurons (a simplified version of biological neurons in an animal brain). Each connection (a simplified version of a synapse) between artificial neurons can transmit a signal from one to another. The artificial neuron that receives the signal can process it and then signal artificial neurons connected to it.

In common ANN implementations, the signal at a connection between artificial neurons is a real number, and the output of each artificial neuron is calculated by a non-linear function of the sum of its inputs. Artificial neurons and connections typically have a weight that adjusts as learning proceeds. The weight increases or decreases the strength of the signal at a connection. Artificial neurons may have a threshold such that only if the aggregate signal crosses that threshold is the signal sent. Typically, artificial neurons are organized in layers. Different layers may perform different kinds of transformations on their inputs. Signals travel from the first (input), to the last (output) layer, possibly after traversing the layers multiple times.

The original goal of the ANN approach was to solve problems in the same way that a human brain would. However, over time, attention focused on matching specific tasks, leading to deviations from biology. ANNs have been used on a variety of tasks, including computer vision, speech recognition, machine translation, social network filtering, playing board and video games, process automation and medical diagnosis.

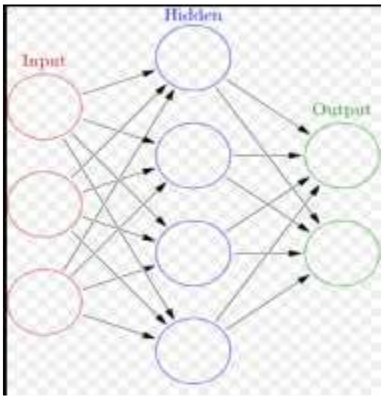

Figure 7: The ANNs context

Each artificial neuron (Fig.8) consists of multiple inputs xi and a single y output. Each input xi "weighs" with a weight wi and the results are summed through the summation function F:

$$F = \sum_{i}^{n} x_i w_i \qquad (1)$$

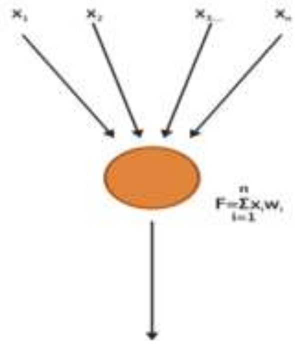

Figure 8: The structure of artificial neuron

The next figure shows some basic types of ANNs:

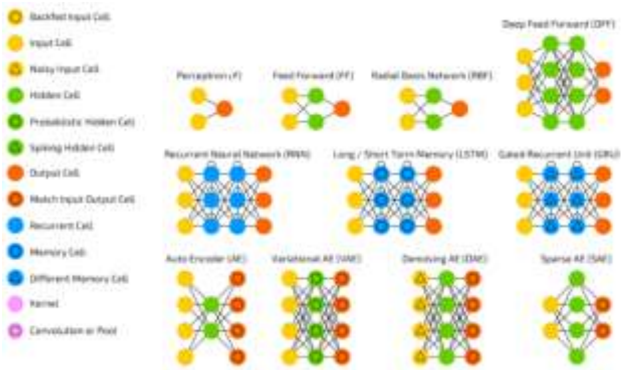

Figure 9: The basic types of ANNs

3.6. SMART SENSORS

A smart sensor is a device (Fig.10) that takes input from the physical environment and uses built-in compute resources to perform predefined functions upon detection of specific input and then process data before passing it on. Smart sensors enable more accurate and automated collection of environmental data with less erroneous noise amongst the accurately recorded information. These devices are used for monitoring and control mechanisms in a wide variety of environments including smart grids, battlefield reconnaissance, exploration and a great number of science applications.

The smart sensor is also a crucial and integral element in the Internet of Things (IoT), the increasingly prevalent environment in which almost anything imaginable can be outfitted with a unique identifier (UID) and the ability to transmit data over the Internet or a similar network. One implementation of smart sensors is as components of a wireless sensor and actuator network (WSAN) whose nodes can number in the thousands, each of which is connected with one or more other sensors and sensor hubs as well as individual actuators.

Compute resources are typically provided by low-power mobile microprocessors. At a minimum, a smart sensor is made of a sensor, a microprocessor and communication technology of some kind. The compute resources must be an integral part of the physical design -- a sensor that just sends its data along for remote processing is not considered a smart sensor.

A smart sensor may also include a number of other components besides the primary sensor. These components can include transducers, amplifiers, excitation control, analog filters and compensation. A smart sensor also incorporates software-defined elements that provide functions such as data conversion, digital processing and communication to external devices.

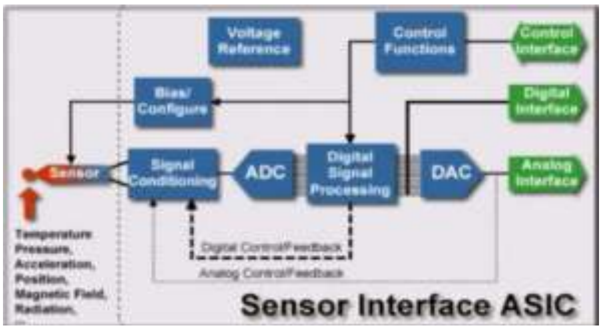

Figure 10: The general architecture of smart sensor

3.7. INTERNET OF THINGS (IOT)

The Internet of things (IoT) is the network of physical devices, vehicles, home appliances and otheritems embedded with electronics, software, sensors, actuators, and connectivity which enables these objects to connect and exchange data. Each thing is uniquely identifiable through its embedded computing system but is able to inter-operate within the existing Internet infrastructure. The IoT allows objects to be sensed or controlled remotely across existing network infrastructure, creating opportunities for more direct integration of the physical world into computer-based systems, and resulting in improved efficiency, accuracy and economic benefit in addition to reduced human intervention. When IoT is augmented with sensors and actuators, the technology becomes an instance of the more general class of cyber-physical systems, which also encompasses technologies such as smart grids, virtual power plants, smart homes, intelligent transportation and smart cities.

"Things", in the IoT sense, can refer to a wide variety of devices such as heart monitoring implants, biochip transponders on farm animals, cameras streaming live feeds of wild animals in coastal waters, automobiles with built-in sensors, DNA analysis devices for environmental/food/pathogen monitoring, or field operation devices that assist firefighters in search and rescue operations. Legal scholars suggest regarding "things" as an "inextricable mixture of hardware, software, data and service".These devices collect useful data with the help of various existing technologies and then autonomously flow the data between other devices. The term "the Internet of things" was coined by Kevin Ashton of Procter & Gamble, later MIT's Auto-ID Center, in 1999.

The applications for internet connected devices are extensive (Fig.11). Multiple categorizations have been suggested, most of which agree on a separation between consumer, enterprise (business), and infrastructure applications. George Osborne, the former British Chancellor of the Exchequer, posited that the Internet of things is the next stage of the information revolution and referenced the inter-connectivity of everything from urban transport to medical devices to household appliances.

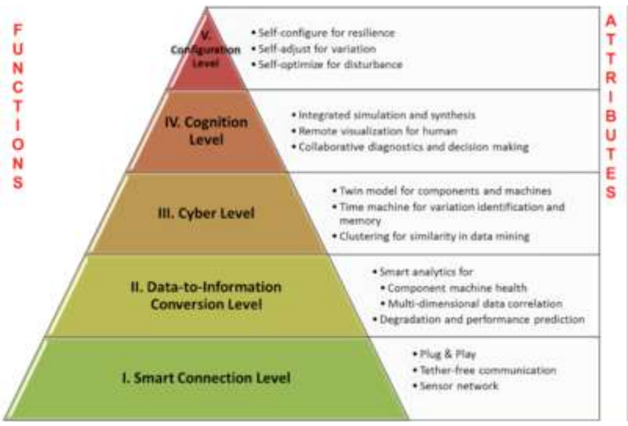

Figure 11: The IoT in Process Automation - Design architecture of cyber-physical systems-enabled manufacturing system

3.8. ROBOTICS

Robotics is an interdisciplinary branch of engineering and science that includes mechanical engineering, electrical engineering, computer science, and others. Robotics deals with the design, construction, operation, and use of robots, as well as computer systems for their control, sensory feedback, and information processing (Fig.12).

These technologies are used to develop machines that can substitute for humans and replicate human actions. Robots can be used in any situation and for any purpose, but today many are used in dangerous environments (including bomb detection and de-activation), manufacturing processes, or where humans cannot survive. Robots can take on any form but some are made to resemble humans in appearance. This is said to help in the acceptance of a robot in certain replicative behaviors usually performed by people. Such robots attempt to replicate walking, lifting, speech, cognition, and basically anything a human can do. Many of today's robots are inspired by nature, contributing to the field of bio-inspired robotics.

Robotics is a branch of engineering that involves the conception, design, manufacture, and operation of robots. This field overlaps with electronics, computer science, artificial intelligence, mechatronics, nanotechnology and bioengineering.

There are many types of robots; they are used in many different environments and for many different uses, although being very diverse in application and form they all share three basic similarities when it comes to their construction:

1. Robots all have some kind of mechanical construction, a frame, form or shape designed to achieve a particular task. For example, a robot designed to travel across heavy dirt or mud, might use caterpillar tracks. The mechanical aspect is mostly the creator's solution to completing the assigned task and dealing with the physics of the environment around it. Form follows function.
2. Robots have electrical components which power and control the machinery. For example, the robot with caterpillar tracks would need some kind of power to move the tracker treads. That power comes in the form of electricity, which will have to travel through a wire and originate from a battery, a basic electrical circuit. Even petrol powered machines that get their power mainly from petrol still require an electric current to start the combustion process which is why most petrol powered machines like cars, have batteries. The electrical aspect of robots is used for movement (through motors), sensing (where electrical signals are used to measure things like heat, sound, position, and energy status) and operation (robots need some level of electrical energy supplied to their motors and sensors in order to activate and perform basic operations)
3. All robots contain some level of computer programming code. A program is how a robot decides when or how to do something. In the caterpillar track example, a robot that needs to move across a muddy road may have the correct mechanical construction and receive the correct amount of power from its battery, but would not go anywhere without a program telling it to move. Programs are the core essence of a robot, it could have excellent mechanical and electrical construction, but if its program is poorly constructed its performance will be very poor (or it may not perform at all). There are three different types of robotic programs: remote control, artificial intelligence and hybrid. A robot with remote control programing has a pre-existing set of commands that it will only perform if and when it receives a signal from a control source, typically a human being with a remote control. It is perhaps more appropriate to view devices controlled primarily by human commands as falling in the discipline of automation rather than robotics. Robots that use artificial intelligence interact with their environment on their own without a control source, and can determine reactions to objects and problems they encounter using their pre-existing programming. Hybrid is a form of programming that incorporates both AI and RC functions.

Figure 12: The industrial robotics

IV. Conclusion

In summary, it has been found from this paper that future process automation will be based on the following technologies and methods:

- Digital and intelligent control,
- Artificial intelligence (mechanical learning, artificial neural networks),
- The Internet of Things (IOT), and
- Robotics.

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