ARCHITECTURES AND METHODS FOR COMPUTER-BASED AUTOMATION

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Summary

The present paper introduces to the field of industrial automation, meaning the automation of technical processes using modern computer and information technologies. This manifold engineering discipline is gaining more and more importance, not only because of the rapidly ongoing innovation of underlying technologies but also because it is infiltrating more and more spheres of our every day and working life. Many years primarily plant automation was in the focus of interest, i.e. the automation of technical processes in industrial plants such as chemical processes in process industry or production processes in factories.

Apart form that also product automation has evolved and constitutes a major division of industrial automation, today. Product automation stands for the automation of technical processes running in mass or bulk products, such as motor vehicles or washing machines. Often theses products consist of several computer nodes networks by means of bus systems so that in terms of complexity of the automation task they are in no way inferior to huge industrial plants.

The automation engineer of today – this is true for plant and product automation as well – is required not only to have a good knowledge of the respective automation methods but also to be aware of computer and information technologies. This contribution intends to impart the expertise needed in this borderland between conventional automation and applied software engineering. It provides a solid fundament of basic knowledge and skills as well as an introduction to the most important methods for joining both, automation and software.

1. Definition of some Basic Terms

1.1 The Term “Technical Process”

A process (derived from the Latin procedere = to proceed) is a procedure, an operation, basically something dynamic. An operation which occurs in a technical system causes a change in the state of material “things”, energy or information. Therefore the first definition of the term “technical process” is:

> *A technical process is an operation which changes the state of material, energy or information. This change in state can also cause an initial state to be transformed to a final state.*

Figure 1 illustrates this definition, Table 1 shows some examples.

Another definition can be found by considering the time sequence of all events during a state change and focusing on the retrieval of process results (e.g. in observation) and the manipulation of the process sequence (e.g. as in process control). From this position DIN 66201 is defined as:

A process is the sum of events that affect each other in a system which causes material, energy or information to be transformed, transported or stored. A technical process is a process consisting of physical values that can be acquired and manipulated with technical means.

Figure 1: *Technical process* as an event that causes a change in state. For example an initial state can transit to a final state

In figure 2 this definition has been combined with the definition according to figure 1. Here it is assumed that the state variables of the technical process can be acquired as physical values via technical means i.e., with so-called detectors or sensors, and that state transitions can be influenced by so-called actuators. In figure 2 material, energy or information inflows and outflows have been drawn to indicate that a transition from an initial state to a final state is possible, as in figure 1, as well as a continuous transformation of the inflow of material, energy and information to the corresponding outflow.

Initial State	**Technical Process in a technical system**	**Final State**
Low ambient temperature	Thermal process regarding house heating with an oil-fueled heating system	Higher ambient temperature
Dirty laundry	Washing process in a washing machine	Fresh laundry
Unsorted parcels	Transportation and distribution process in a parcel distribution system	Parcels sorted by destinations
Energy of fossil or nuclear fuels	Enegry transformation and energy generation processes in a power plant	Electric energy
Parts to be stored	Storage process in a high bay warehouse	Parts compiled for commissions
Train at location A	Traffic process of a train journey	Train at location B
Monomere substance	Process in a chemical reactor	Polymeric substance
Untested device	Test process in a test laboratory	Tested device
Parts without a drill-hole	Drilling process of a drilling machine	Parts with drill-hole
Pollutants	Process in a system for pollution monitoring	Information on pollution concentrations are indicated in monitoring center

Table 1: Definition examples of the term “technical process” acc. to figure 1

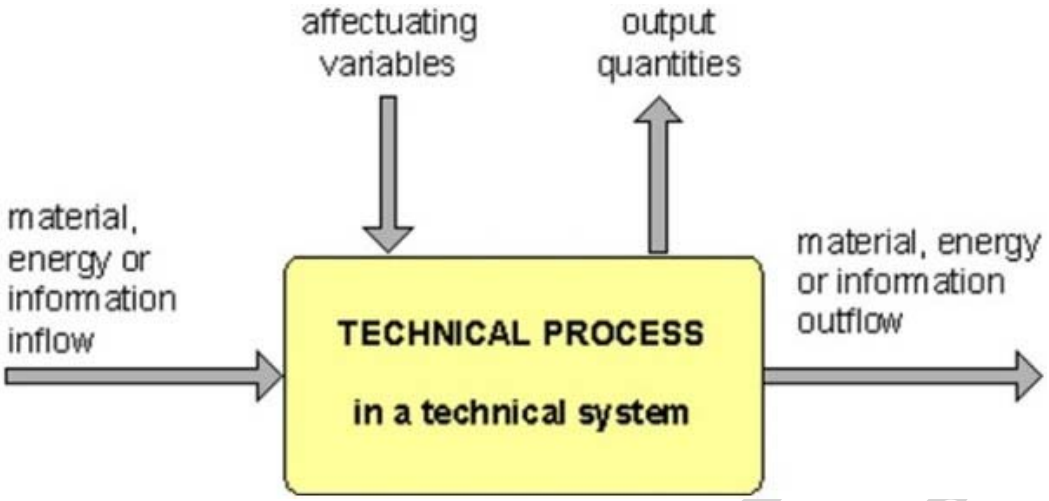

Figure 2: Definition of a technical process as the sum of events which acquire physical values result values) with technical means and influence them (actuating variable)

As shown in figures 1 and 2, one must differentiate between a technical process and a technical system, in which the process takes place. For example we differentiate between the washing process and the washing machine in which the washing process takes place. The examples of technical systems in Table 1 consist of technical products (e.g. a washing machine) and technical plants (e.g. a parcel distribution center or a power plant).

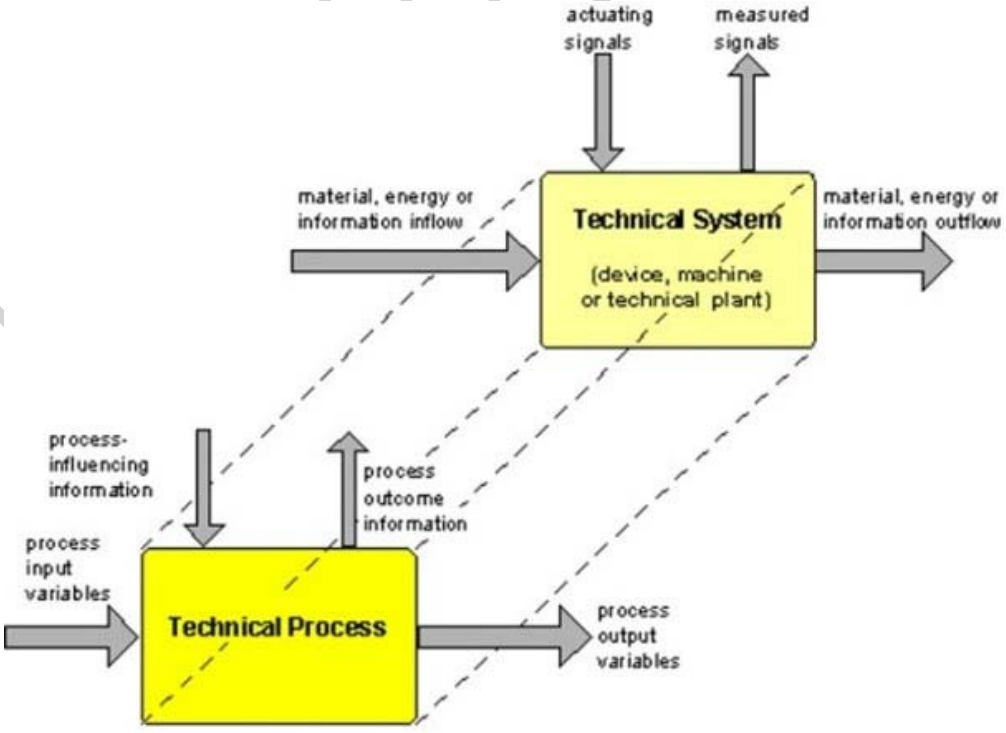

Figure 3: Graphic expression of the difference between a technical system (a technical product or technical plant) and the technical process running on it.

In order to graphically express the difference between a technical process and the technical system concerned as in figure 3, the technical system and the contained technical process are illustrated as two sides of a total system (cuboid).

Figure 4 shows an example for this type of illustration in the area of chemical process engineering. From a strongly simplified viewpoint the technical plant shown is a chemical reactor which is filled with two substances A and B in order to create an output product.

The technical process which takes place in this technical plant consists of three partial processes:

- Filling the reactor with the substances A and B.
- Reaction of the two substances so that a reaction product is created.
- Emptying (pumping) the resulting reaction product.

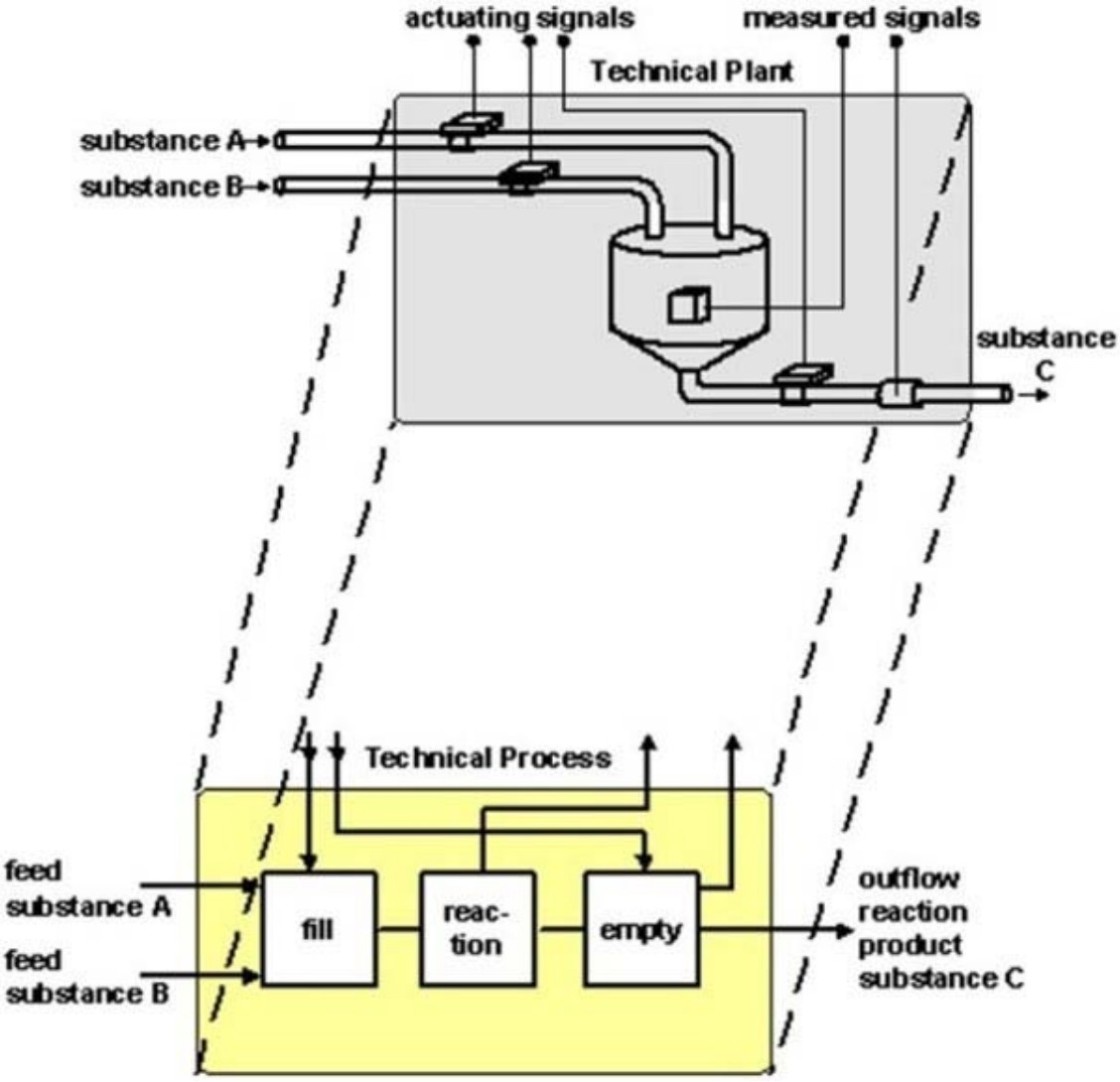

Figure 4: Example for a technical plant (chemical reactor) which is running a technical process

1.2. The Term "Industrial Automation"

A self-acting working technical system is called an automate e.g., a *cigarette vending machine* or a *ticket vending machine.* Therefore the term "automation" is generally used whenever machines, devices or technical plants are put into a position to work automatically with the help of electrical, mechanical, pneumatic or hydraulic equipment. In most cases human actions are replaced by machine equipment. The term "*industrial automation"* indicates, as a specification of the general term "automation", the specific field dealing with the automation of (any) technical process. Other special fields for example are *office automation*, *traffic automation*, *train automation*, etc.

A ***industrial automation system*** consists of three types of systems that are related to each other:

- A technical system (a technical product or a technical plant), in which a technical process (the transformation, conversion and transport of material or energy takes place.
- A computer or communication system, in which an information process takes place (transformation, conversion and transport of information). It serves to acquire, calculate and present information about the process events as well as to output information with the aim of controlling the technical process in the desired manner.
- The process control personnel, also called people, that observe the process events via the according presentation media, that control and influence these events or, in case exceptional situations or disturbances should arise, must react accordingly.

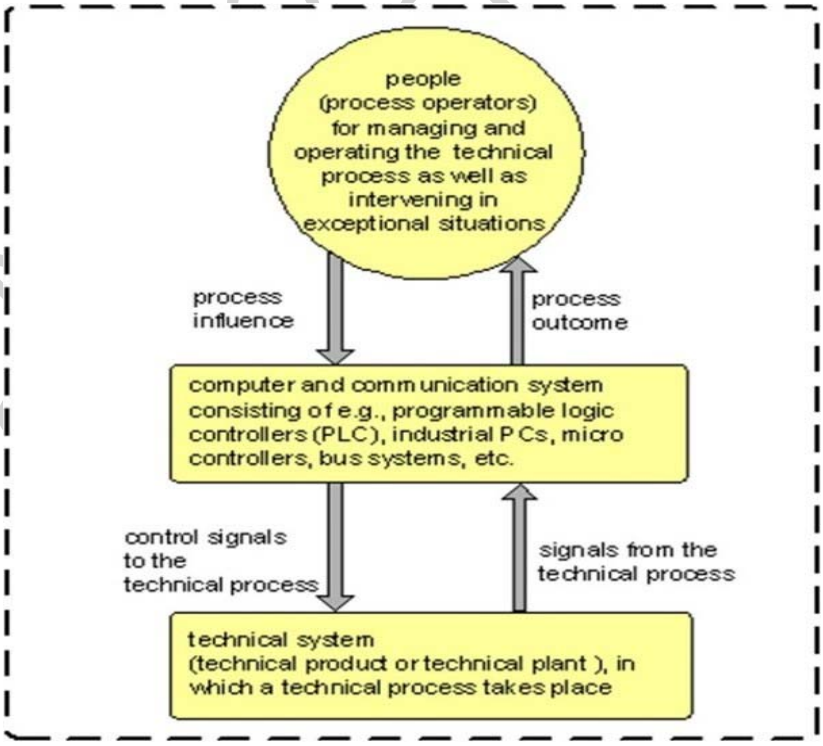

Figure 5: The industrial automation system consists of a technical system, a computer and communication system as well as humans (process personnel)

If the examples for technical processes from Table 1 or the corresponding technical systems were inserted into figure 5 then the interaction of the three system types could be recognized in all cases: The technical processes named in Table 1 – heating process, washing process, transport and distribution process of a parcel distribution center – are normally controlled by a fully automated computer system. The human must only provide target values and operation modes and react in case of an emergency.

The other examples in Table 1 demand more responsibility from the personnel in controlling these technical processes (as in operating a power plant, driving a train, controlling chemical reactions or executing tests in a test field).

The total system illustrated in figure 5 can be seen from different viewpoints. Different terms are derived from these viewpoints:

- If the aim is to automate the technical process in a technical system with the help of information processing units, so that the human is only required to present his desired operational result (e.g. setting the desired temperature on the thermostat of a heating system), then this is called *industrial automation.*
- If the primary focus is the task of the human controlling the sequence of the total technical process, while being supported by the automation of individual processes, then the term *instrumentation and control* is correct.
- From the viewpoint of the field computer science the system is considered to be a specific type of information processing, which is unique in that it does not solve commercial or scientific problems. The goal is to connect a computer system with a technical system. This view leads us to the terms ***process data control*** or ***process computation***.

The various terms stem from considering the operation of the partial systems in figure 5 from different viewpoints or with different aims. Different aspects are emphasized: the automation, control by humans or the type of information processing taking place. It follows that the terms are to be considered synonyms.

The more events in a technical process are automated, the more the term "*industrial automation*" is justified (i.e. even if some of the procedures have not been automated yet due to high costs!).

Sometimes the type of technical process to be automated is differentiated according to

- Process engineering automation (industrial automation of (chemical) processing plants)
- Production process automation (production automation).

Another definition method relates to the automation of individual products (e.g. mass products like washing machines) or complete technical plants. In this case product automation and plant automation are distinguished. This will be discussed in more detail in the following section 1.3.

The industrial automation system presented in figure 5 which shows a technical system (a product or a plant), a computer and communication system, as well as people connected with each other, also shows how three types of processes (events) interact:

- The technical process in the technical system,
- The information process in the computer and communication system,
- The cognitive process (thinking process) in the minds of the people that are supervising or controlling the technical process.

Each of these processes usually consists of partial processes that communicate with each other.

Figure 6 shows how these various processes interact within a industrial automation system.

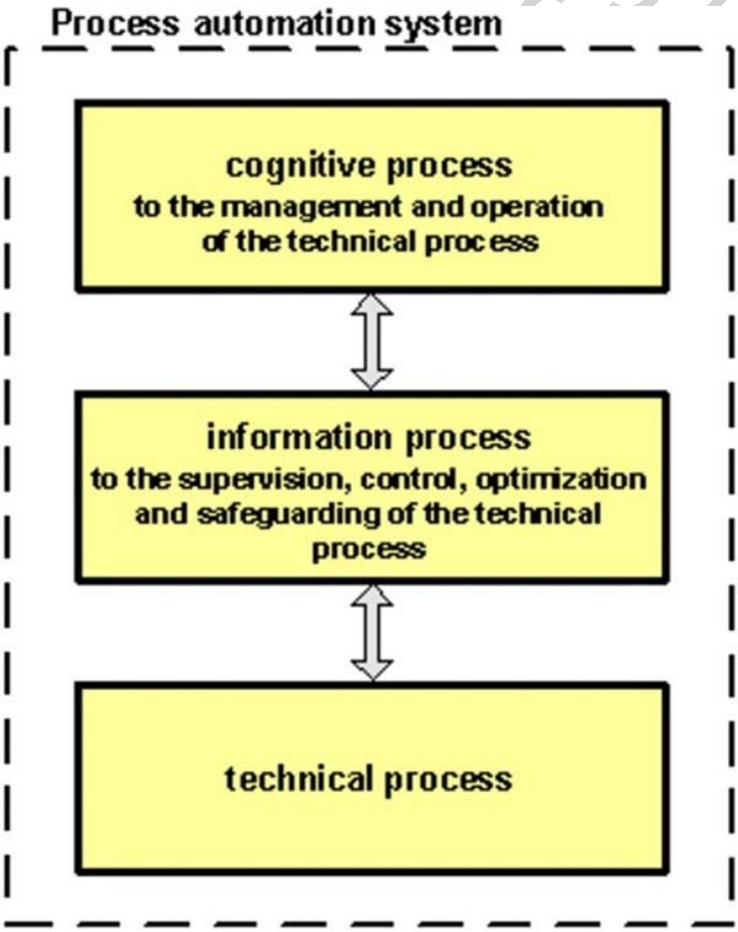

Figure 6: The interaction between the technical process, the information process and the cognitive process in a industrial automation system

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Biographical Sketch

Prof. Dr.-Ing. Dr. h. c. Peter Göhner is director of the Institute of Industrial Automation and Software Engineering at the University of Stuttgart. His major fields of activity are: applied software engineering, component-based development of automation systems, reliability and safety of automation systems, application of Internet technologies in automation, agent-oriented automation system architectures and multimedia-assisted education. Since October 2000 he is also the prorector of education of the University of Stuttgart.