GUEST CONTRIBUTION

AUTOMATED ENGINEERING:

SYSTEMS ENGINEERING FOR INDUSTRY 4.0

WHY AUTOMATED ENGINEERING?

More than a few grounded mid-sized businesses express frustration at the almost continual introduction of new slogans in the IT industry. Do these glossy words amount to anything more significant than simply disguising the old under the cloak of the new? With respect, the (seemingly) dumb question must then be asked: Why do we need “automated” engineering anyway?

American pragmatism cuts straight to the point: many American campuses have been offering courses on automated engineering through their engineering faculties for many years now. The (American) industry is under increasing pressure to find new ways of reducing costs and increasing efficiency. To achieve this, automation must integrate various production processes and sales steps while reducing time and resources. An engineer who wants to achieve this needs interdisciplinary skills. Being highly specialized with a classical engineering degree is not enough. Automation engineers must have a command of design, integration, programming, simulation, testing and the control of various machines and processes. Their skill set must include managing complex problems, creative thinking, attention to detail and the ability to integrate and communicate within a diverse team. If they can do this, lucrative jobs beckon. Because, actually, which companies can seriously do without such capabilities?

AUTOMATED ENGINEERING REQUIRES SYSTEMS ENGINEERING

Automated engineering is by no means new; it has had a long preliminary phase in industrial history. In the 1940s, complex engineering arose where various technology fields began to intersect. Examples in the USA initially included military projects, then space travel (e.g. the Apollo program) and, finally, civil projects: from bridge building to computer and robot applications in industry, right up to major infrastructure projects. Mechatronics were the next important development step, where the collaboration of mechanical engineering and electronics created a new specialist field. In general, complex tasks arise when problem solving involves combining different specialist fields. This challenge becomes extreme when it is no longer just about one manufacturing process, but an entire production and supply process within a factory.

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Be it in space travel or the production environment – complex tasks are a challenge for engineers. Interdisciplinary cooperation and automated engineering can help to master it.

This leads us to a complex system in which many different components work together. In the natural sciences, complex systems are researched in various disciplines. Such examples from the natural sciences can definitely inspire our engineering approaches. A cell works as a complex biochemical factory, where different process workflows organize themselves. The central nervous system coordinates different process cycles in an organism like the complex circuit diagrams of an electronic system. Even an ecological system consists of many different factors to form a complex infrastructure. Ecological systems are resilient and robust if they are not continually disrupted. In all these natural science cases, complex systems can be simulated through mathematical models and computer systems in order to derive explanations and prognoses.

Since at least the 1990s, the term "Systems Engineering" has become commonplace in the engineering field. Even as early as the 1950s, the ingenious American engineer Jay Wright Forrester (also pioneer of the RAM memory) had established a mathematical and computer-based system theory with which, for example, industrial processes and city infrastructures could be designed for the first time. Forrester became well-known in the 1970s for his first ecological models for the Club of Rome.

Around this time, the first software tools in IT to model and simulate complex engineering projects were developed, including Unified Modeling Language (UML). UML is a graphical modeling language for the specification, construction and documentation of software parts and other systems. Project managers can use this to verify system requirements which business analysts have modeled in UML. Software developers realize workflows that business analysts have described in UML in collaboration with specialists. System engineers install and operate software systems based on installation plans that have been designed in UML.

A further example of systems engineering is Quality Function Deployment (QFD) which Toyota has used since the 1980s to conceptualize, create and sell customer-oriented products and services. QFD makes this possible by integrating quality control across all company departments.

In 1990, the National Council on Systems Engineering (NCOSE) was established in the United States, and then expanded to the International Council on Systems Engineering (INCOSE) in 1995. It is concerned with common standards for the education of system engineers who distinguish themselves through interdisciplinary abilities and who should follow a holistic approach in their problem solving.

But how can not just individual manufacturing processes but also complex systems become automated? This is the challenge of Systems Engineering today when it comes to automation of factories, housing and infrastructures. In IT, we talk of cyber-physical systems. One example is an airport where various domains need to be coordinated into a software. Here, there is not only the technology domain (e.g. aircraft), but also the baggage logistics domain and, ultimately, the passenger domain. Each of these domains is defined by different semantics. These must be coordinated and common standards and protocols developed. This example makes the complexity of the demands on System Engineering very clear: the model is not only about technical and economical parameters. Cyber-physical systems require people (such as the passengers in our example) to be integrated.

AUTOMATED ENGINEERING AND THE FUTURE OF INDUSTRY 4.0

The most popular application of a cyber-physical system today is the Industrial Internet (Industry 4.0). The Internet of Things, where objects and devices of any kind communicate via sensors, will now extend to production and machine parts. So it is not just about communication from person to person or person to machine but communication from machine to machine. This is the point where automated engineering meets Cognitive Systems Engineering. Scientifically speaking, Cognitive Systems Engineering deals with the interface between cognitive psychology and systems engineering: how do humans master complexity and how much of it can be automated, and so delegated to machines and software? Where do the strengths of humans lie? At its heart is automating the human-machine interface (HMI).

But Industry 4.0 isn't a doctrine of salvation nor a button that switches German Industry to full automation overnight. It will be much more about the various levels of automation which are differently set up in each company. Therefore, automated engineering should be affiliated with requirement engineering: the exact requirements and demands of an engineer within the complex processes of a company need first to be recognized and defined. This is a process which in some cases may take several months. Normally, external automated engineering experts need to be brought in to work with employees over a longer timeframe, in order to recognize the weaknesses and possibilities for improvement.

The corresponding business model is called "Buy and Build". A typical mid-sized industrial firm would bring in a company which is specialized in software and automation questions and can develop a fitting automation model into its production operations over a long period of time. In the end, in some cases, Industry 3.2 or 3.6 could become an efficient (and more cost-effective) solution.

Automated engineering thereby grounds such noble concepts as Industry 4.0 through the detailed application of automation, on site and in real operations. Specialized companies such as COPA-DATA should, however, not simply collaborate with business. Just as significant is cooperation with science. In COPA-DATA's case this includes working with the Chair of Food Packaging Technology at the Technische Universität München. Research can allow standardized and consolidated use of operating data and the calculation of the key figures necessary to assess the automation interfaces or for a detailed error analysis on site. Institutes of the Fraunhofer Group are also participating in this research. In the end, even our skeptical mid-sized company should be convinced that our most promising future lies in a stronger cooperation with automated engineering.

ABOUT THE AUTHOR:

Prof. Dr. Klaus Mainzer holds the chair for Philosophy and Theory of Science at the Technische Universität München (TUM) and concentrates primarily on the fundamentals and applications of complex systems, artificial intelligence, the Internet of Things and Big Data in nature, technology and communities. He is the author of related books on these topics, such as: "Die Berechenbarkeit der Welt. Von der Weltformel zu Big Data" C.H. Beck, Munich (2014), "Künstliche Intelligenz. Wann übernehmen die Maschinen?" Springer, Berlin (2016)[1]. He is the founding director of the Munich Center for Technology in Society (2012-2014) and headed the Carl von Linde-Akademie (2008-2015) at the Technische Universität München.

[1] *These books are not available in English translation at the current time, only in the German original.*