Unchain the shopfloor with Software Defined Automation

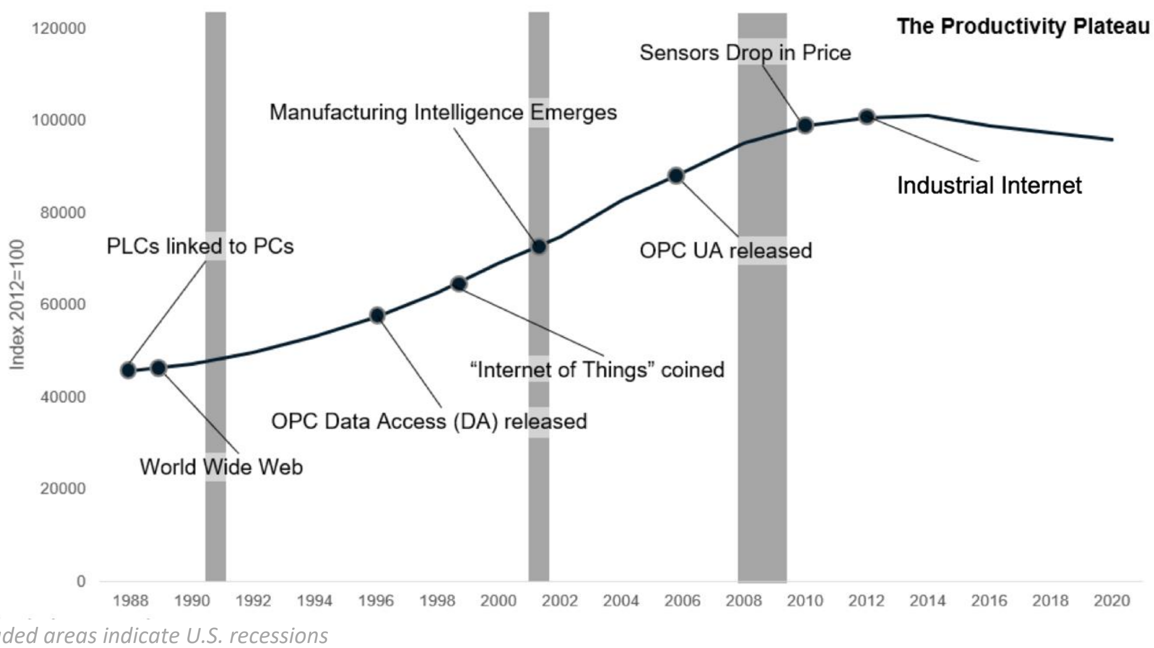
Where do we stand now?

While Software Defined Automation has been discussed for a few years (Josef Waltl, 2018), surprisingly little innovation has happened in the field. Recently, however, we have been seeing more traction and expect to see some promising changes in the industry landscape when it comes to transforming today's factories. This article provides an overview of the current state and outlines concrete ways to implement highly flexible and efficient production systems powered by Software Defined Automation.

Industry 4.0 – A historical perspective

The 4th industrial revolution promises to transform manufacturing in its scale, scope, and complexity. Two-thirds of industrial companies worldwide name the digitization of their production value chain as one of their highest priorities (McKinsey, 2018). Where traditional productivity levers that enabled a lean transformation in the 70s and 80s have been exhausted, the benefits from outsourcing and offshoring in the 90s are now also reaching a limit. Labor productivity has increased dramatically since the 80s but has been stagnating over the past decade (U.S. Bureau of Labor Statistics, 2022). Industry 4.0 or Industrial Internet of Things (IIoT) technologies are promising to change this and unleash the next level of performance improvements (McKinsey, 2018).

Figure 1 - Manufacturing Sector: Labor Productivity (Output per Hour) for All Employed Persons



Shaded areas indicate U.S. recessions

Source: Bureau of Labor Statistics (2022) | fred.stlouisfed.org

IIoT technologies are proliferating, and large amounts of data are gathered and used to feed machine learning algorithms and enhance manufacturing and industrial processes. IIoT uses the power of smart machines and real-time analytics to leverage data produced by up until that point ‘disconnected’ machines in industrial environments. Insights from these smart machines drive better, faster, and more accurate business decision-making.

Use cases pursued by industrial manufacturers can be divided into one of the following three areas:

1. Data aggregation and context enrichment
This involves all technologies that allow for real-time transmission of information to the right decision-makers, such as digital-enabled performance management and the use of augmented reality for interactive work instructions and standard operating procedures.

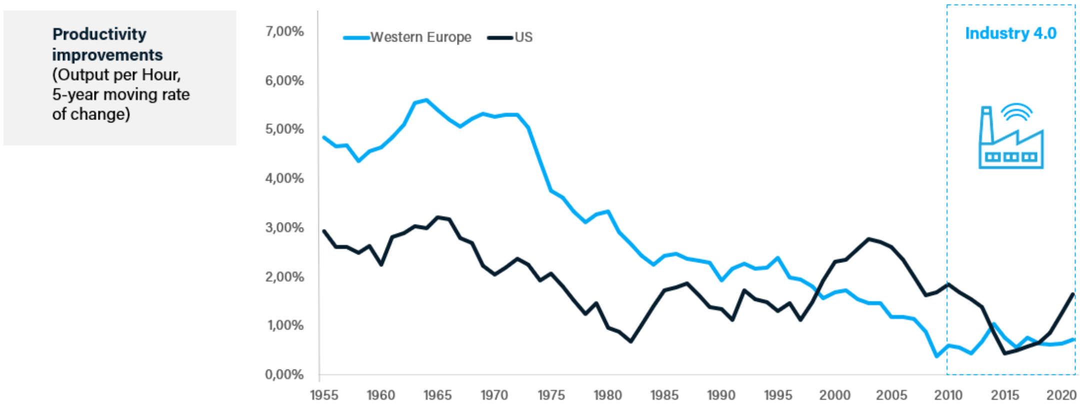
2. Intelligence
Advanced analytics and artificial intelligence (AI) are applied to a large range of data which allows for the generation of new insights to inform decision making. Use cases include condition monitoring and predictive maintenance, digital quality management or AI-driven demand forecasting.

3. Flexible automation
IIoT also empowers advanced and more flexible automation on the shop floor. An ever-increasing number of product variants and an increasing technical complexity of products and manufacturing processes are driving the need for more flexible automation solutions.

Factories are humming – where is the problem?

While IIoT technologies promise significant potential, the reality is that 10 years of Industry 4.0 have not moved the needle in factory productivity. The manufacturing industry is looking for continuous adaptability and resilience of production facilities and their ongoing optimization, however, the average utilization of factories is still only at around 80% in the EU and 76% in the US (Moody's Analytics, 2022).

Figure 2 – Productivity improvements Europe vs. US



Source: "The industry anatomy of the transatlantic productivity growth slowdown", Robert J. Gordon, Northwestern University (2021)

Industrial manufacturers across the globe are stuck in "pilot purgatory"– having significant activity underway by testing several use cases, but are unable to roll out digitally-enabled use cases across their factory network to capture significant or meaningful benefits from this on their bottom line (McKinsey, 2018). 60 percent of IoT initiatives stall at the proof-of-concept stage (PoC) and only 26 percent of companies consider their IoT initiatives a success (Cisco, 2017).

A key reason for the slow adoption of transformative technologies is the historical disconnect between Information Technology (IT) and factory automation technologies or Operations Technology (OT) as mentioned above. Whilst Information Technology (IT) has radically evolved over the past decades including cloud computing adoption, virtualization of workloads and the use of modern programming paradigms including GIT-based version control, factory automation technologies have evolved much more incrementally. While corporate core IT systems (PLM, SCM, CRM, ERP) are well on their way to getting cloud-based services, for example, any change in the core function of the manufacturing line is often only reflected in a mail to the automation engineering department describing the needed change.

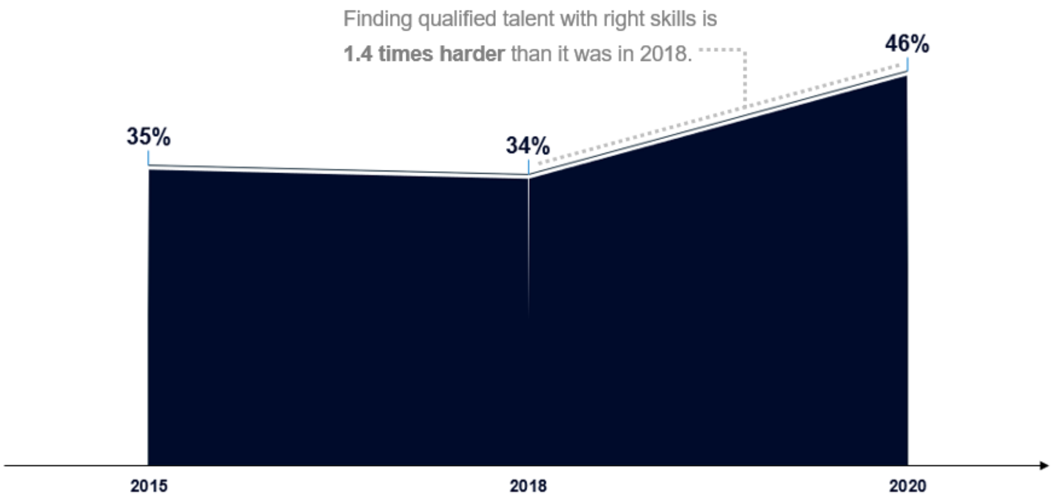
To draw an analogy with the IT world, for building web applications, developers can use common programming skills to create an application in the cloud and deliver it seamlessly to its users on their smartphones, laptops, or desktop PCs. The bridge between cloud-based IT systems and users' endpoints is already there. To develop and deploy IIoT applications, however, manufacturers must build their own "bridge" between their Information Technology (IT) systems and their factory automation technology – also referred to as Operations Technology (OT). They are required to:

- Use various communication protocols to integrate embedded modules, gateways, and other edge devices into their industrial equipment,
- Connect such edge devices to a network and then manage these connections in a way that minimizes data transmission costs,
- Build or find application interfaces (APIs) that integrate the edge device data into cloud-based IT systems,
- And finally, ensure all data is transmitted and stored in a secure way.

- Implement often use case and automation vendor-specific re-parametrization services to bring insights into action.

A second major reason is that manufacturers across the globe are challenged with the shortage of skilled specialists such as automation engineers, software developers, and industrial data scientists.

Figure 3 - Finding qualified talent is harder than it's been



Source: Deloitte analysis of data from multiyear Deloitte and The Manufacturing Institute skills research studies. Deloitte Insights | deloitte.com/insights

What is more, a Deloitte Study from 2022 showed that Covid-19 added hardship to the already unabated manufacturing skills gap in the US, which could leave as many as 2.1 million jobs unfilled by 2030 (Wellener, et al., 2021). More than a decade of growth in manufacturing jobs was erased by the initial pandemic outbreak which is worsened by the already existing shortage of talent in the manufacturing industry. The National Association of Manufacturers (NAM) found that "attracting and retaining a quality workforce remains one of the top challenges for manufacturing firms (The National Association of Manufacturers, 2020). Executives reported being unable to fill higher-paying entry-level production positions, let alone skilled specialists. The US economy alone is estimated to lose $1tn in 2030 from a lack of skilled manufacturing workers (Deloitte, 2022).

We see a consistent pattern across our larger customer base that the aged technology stacks and outdated programming languages and software tools lead to a lack of interest in talent for industrial engineering jobs. Our brightest technical talent in the 2020s simply prefers code in modern programming languages like Python and Golang, which are easily deployed in cloud infrastructure over IEC 61131/3 Industrial Automation languages from the 1990s which then often need to be deployed by physically connecting to a Programmable Logic Controller (PLC) in the field. Moreover, every major vendor has implemented its own variant which forces Automation Engineers to choose one technology stack for life. On the other hand, cloud developers collaborate with GIT as a version control system which is just being adapted by the automation vendor community. Clearly, we need to provide the tools to motivate the brightest minds tackling the toughest problems in industrial manufacturing – in particular given the sheer lever this sector has on wealth and resource consumption. For example, in Canada, the manufacturing sector accounts for around 30% of the nation's energy consumption (Statistics Canada, 2021).

The challenge in 2022, or why do factories still have their lights on?

We argue that today's factory automation technology is a major bottleneck for productivity. Organizations need to remain agile and nimble in an ever-changing global marketplace. Automation systems and process control systems have been and will continue to be critical enablers in this adoption. However, the impact of adjusting an existing production line is often more expensive than creating a whole new line. On the one hand, manufacturers are struggling to increase their productivity and unlock the remaining 20% utilization gap of their production lines without comprising more resources (economic and environmental). On the other hand, automation vendors' innovation does not seem to be on par with innovation in the software and IT industry and established vendors seem unable to serve the evolving needs of the market (World Economic Forum, 2021). The IT/OT gap, in particular, the programming of industrial controllers or PLCs is putting a halt to what could be a promising shift for Industry 4.0. In simple words: We often know what to change but can't for outdated technology.

PLC programming is a surprisingly manual and repetitive task, and the manufacturing industry, therefore, remains largely reliant on manual labor when it comes to making changes to their manufacturing processes. An expensive, well-trained, and experienced automation engineering workforce is being used to perform tasks that are 60-70% repetitive based on our firsthand data from manufacturers we work with. The earlier mentioned talent gap is worsening this and forcing businesses to reactivate personnel from retirement (Wilson, 2021).

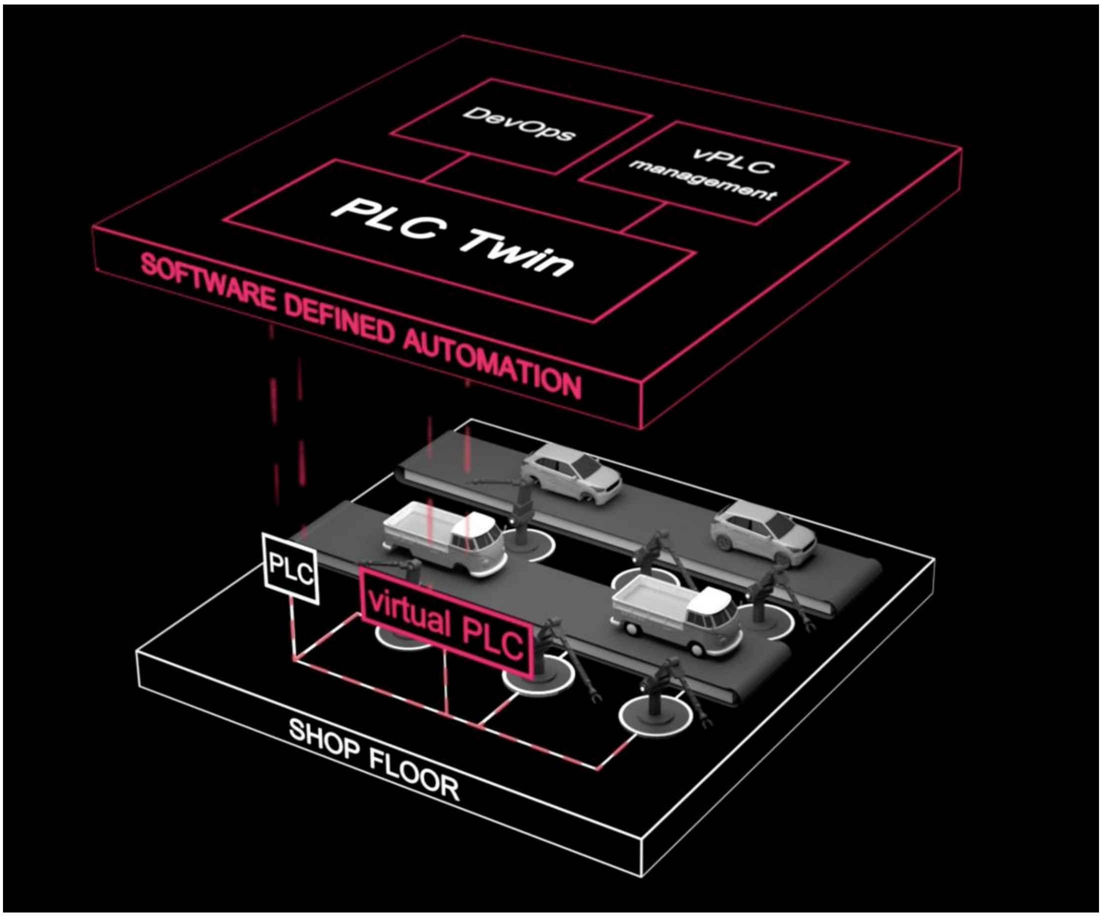
In addition, the tight coupling of hardware and software in common industrial controllers has produced a plethora of vendor-specific hardware architectures and the use of application-specific integrated circuits (ASIC) instead of the standard off-the-shelf CPUs. The global chip crisis in 2020/2021 resulted in limited chip supply for these niche applications and ultimately led to skyrocketing delays in the delays of PLCs and automation equipment. This vulnerability has decreased trust in niche hardware architectures for industrial control. In a time of semiconductor shortages which are causing turbulent disruptions in the manufacturing industry (Wilson, 2021), effective factory automation is difficult.

In summary, the limitations of today's automation technology are:

1. Custom and manual programming with limited re-usability
2. Monolithic solutions are unable to quickly adapt to the demand for versatility
3. Tight coupling of proprietary hardware and software real-time runtimes prevents manufacturers to benefit from virtualization as seen in IT

The concept of a PLC Twin is a way to implement changes in production lines in a secure environment, without damaging real equipment. Industrial automation can be freed from physical limitations when the control code has a digital twin that can be seen as a virtual model of the whole production system. Data aggregation in the cloud and execution of control logic in real-time enabled virtual PLCs near the shop floor can build a fully automated factory optimization loop. In addition, modern software development methods like Git for source control can bring Industrial Automation into the cloud domain and increase the attractiveness for talent. Figure 4 outlines the full vision of Software Defined Automation including all the above-mentioned.

Figure 4 - Software Defined Automation System



Concluding remarks and call to action

A separation of software and hardware in industrial automation will make production lines more adaptable and flexible than ever before, enabling real-time changes in production processes and thereby increasing the utilization of factories and lifting their economic and environmental potential. This promises a significant opportunity to overcome the three obstacles elaborated above.

1. A positive business case can be built as large cost-saving potential can be captured with little up-front investment need. For example, times for changing the behavior of production equipment in their real-time control systems can be reduced from days to minutes, enabling a fully automated “Design to Manufacture” processes. Also,

equipment downtime can be reduced due to real-time updates from the cloud to edge automation layer.

2. Manufacturers can overcome the talent gap in industrial automation by deploying automation engineers more wisely than having them perform repetitive and manual tasks. In addition, they can find more talent as digital PLC twins can be programmed by applying modern software development tools to the automation layer.
3. Remote control of PLCs through the cloud helps bridge the IT/OT gap. Common API interfaces to multiple PLCs breaks proprietary vendor silos in the OT environment and reinforcement learning such as Smart Circle Learning and AI is made possible as control code can be altered in no time.

To wrap it up, firsthand user evidence and macro trends provide evidence that the world needs Software Defined Automation systems to keep productivity growth over decades to come.

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