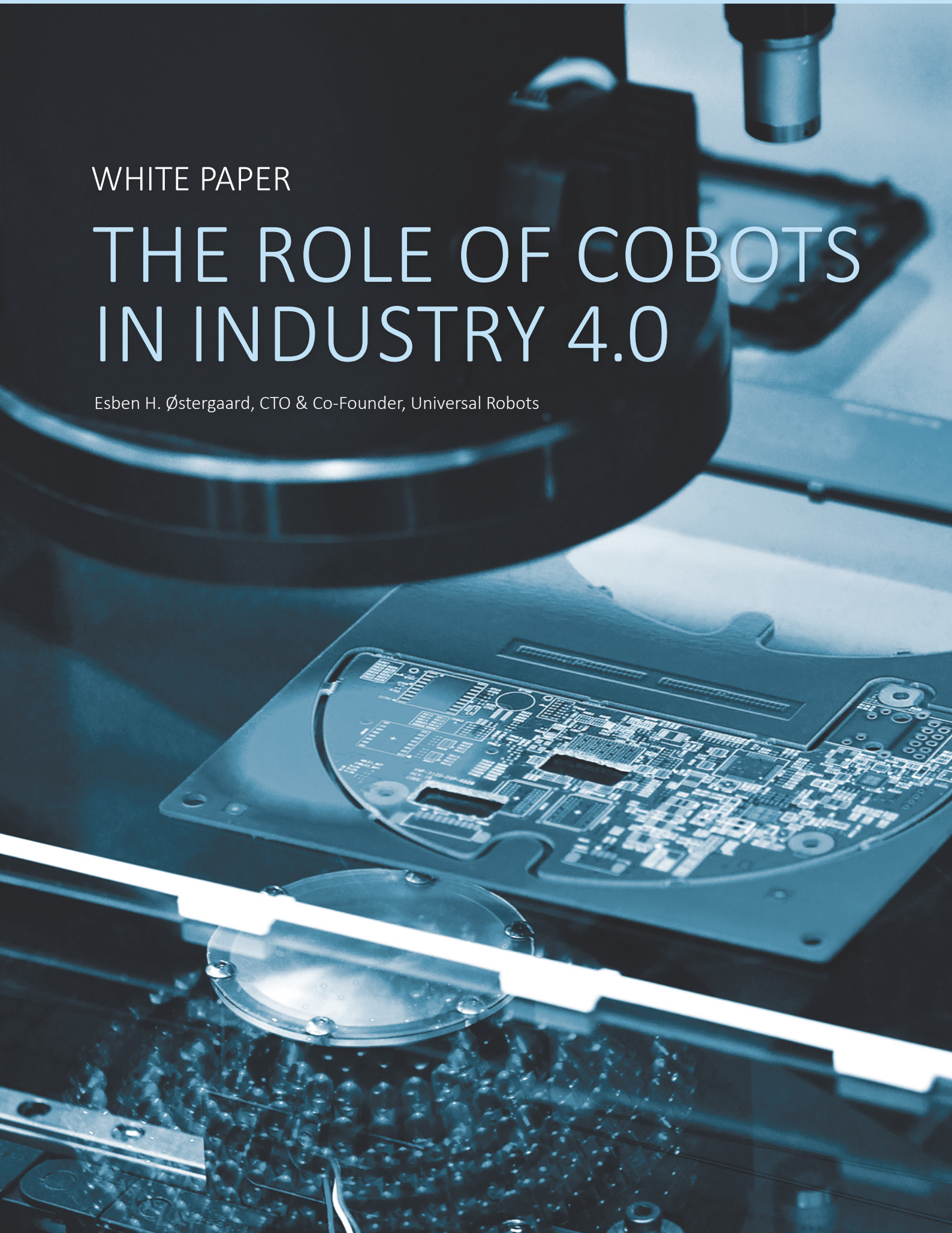
UNIVERSAL ROBOTS



WHITE PAPER

THE ROLE OF COBOTS IN INDUSTRY 4.0

Esben H. Østergaard, CTO & Co-Founder, Universal Robots

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INTRODUCTION

The purpose of this White Paper is to clarify the role that collaborative robots – or "cobots" – play in what has now become known as Industry 4.0. After reviewing the concepts "Industry 4.0" and "cobot," we will examine the suitability of cobots for use in Industry 4.0 environments and the role they play in relation to the whole move towards Industry 4.0. Finally, we will show how the particular nature and capabilities of cobots can shed light on some of the limitations implicit in the Industry 4.0 concept.

INDUSTRY 4.0

Origins of the concept

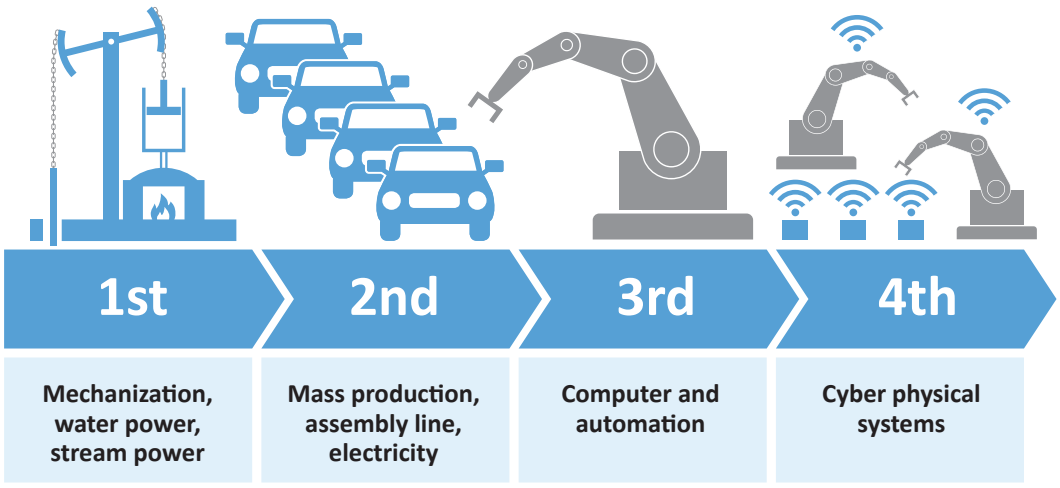
Industry 4.0 (German: "Industrie 4.0") is a catchword used by the German Federal Ministry of Education and Research to refer to the new opportunities that the Fourth Industrial Revolution is creating for German industry.[1] The ministry supports companies' taking advantage of these opportunities through its "Zukunftsprojekt Industrie 4.0" project and the "Plattform Industrie 4.0," which is run jointly with the German Federal Ministry for Economic Affairs and Energy.

Industry 4.0 and the Fourth Industrial Revolution

The term "Fourth Industrial Revolution" is commonly understood to mean a range of manufacturing technologies that fuse the physical and digital worlds, with breakthroughs in artificial intelligence (AI), robotics, the Internet of Things (IoT), autonomous vehicles and 3D printing seen as main drivers.[2]

Unlike Industry 4.0, which applies more strictly to industrial production, the term "Fourth Industrial Revolution" also covers the impact of technological changes on civil society, governance structures, and human identity.[3]

Four industrial revolutions[4]



Definitions of Industry 4.0

The idea of Industry 4.0 has spread far beyond Germany, and is now widely used around the world. The concept has been defined in different ways:

Citing Industry 4.0 Workgroup members, generally considered as the concept's "founding fathers," Wikipedia describes Industry 4.0 as combining cyber-physical systems, the Internet of Things and cloud computing – noting that the result is often referred to as the "smart factory."[5]

The German Federal Ministry of Education and Research envisions "Machines that communicate with each other, inform each other of any faults in the finishing process, identify and order materials that are in short supply – this is the intelligent factory."[6]

In 2015, McKinsey defined Industry 4.0 as "the next phase in the digitization of the manufacturing sector, driven by four disruptions: the astonishing rise in data volumes, computational power, and connectivity, especially new low-power wide-area networks; the emergence of analytics and business-intelligence capabilities; new forms of human-machine interaction such as touch interfaces and augmented-reality systems; and improvements in transferring digital instructions to the physical world, such as advanced robotics and 3-D printing."

At Universal Robots, we think of Industry 4.0 mainly as the internet applied to manufacturing.

Industry 4.0 design principles

A set of Industry 4.0 design principles has been drawn up[7] to help companies identify and implement Industry 4.0 scenarios. These principles are:

- Interoperability: The ability of machines, devices, sensors, and people to connect and communicate with each other via the Internet of Things (IoT) or the Internet of People (IoP).

- Information transparency: The ability of information systems to create a virtual copy of the physical world by enriching digital plant models with sensor data. This requires the aggregation of raw sensor data to higher-value context information.

- Technical assistance: First, the ability of assistance systems to support humans by aggregating and visualizing information comprehensibly for making informed decisions and solving urgent problems on short notice. Second, the ability of cyber-physical systems to physically support humans by conducting a range of tasks that are unpleasant, too exhausting, or unsafe for human workers.

- Decentralized decisions: The ability of cyber-physical systems to make decisions on their own and to perform their tasks as autonomously as possible. Only in the case of exceptions, interferences, or conflicting goals, are tasks delegated to a higher level.

"At Universal Robots, we think of Industry 4.0 mainly as the internet applied to manufacturing."

Criticism

The notion of Industry 4.0 has been criticized as little more than a flashy marketing slogan or journalistic hype. Technological change, these critics note, is something that takes place continuously. Placing a number on any given stage of development – as if it were a software release – oversimplifies the picture and is in fact misleading.[8, 9]

Other critics see a danger for workers and people in general – unless systems are put in place to protect society from the effects of job loss and to ensure that the wealth generated by Industry 4.0 is distributed broadly in society.

Finally, Industry 4.0 proponents and critics alike point to the numerous challenges involved in adopting scenarios based on Industry 4.0-related criteria. Commonly mentioned challenges include:

- Data security issues are greatly increased by integrating new systems and more access to those systems. Proprietary production knowledge then also becomes an IT security problem
- A high degree of reliability and stability are needed for successful cyber-physical communication, and this can be difficult to achieve and maintain
- Maintaining the integrity of the production process with less human oversight could become a barrier
- Loss of high-paying human jobs is always a concern when new automation setups are introduced
- Avoiding technical problems that could cause expensive production outages is always a concern[10]

“The vision was to develop a robot that could serve as a tool for factory workers.”

COBOTS

What is a cobot?

As the name suggests, a collaborative robot (cobot) is a robot designed to collaborate with human workers. In early research and standardization work, the main emphasis was on safety with the aim of allowing robots to work alongside humans. When developing the world’s first commercially successful cobot, Universal Robots realized that ease of programing, a lightweight design and deployment flexibility would also be needed if a robot was to be truly collaborative. The vision was to develop a robot that could serve as a tool for factory workers.

Universal Robots launched the UR5 in 2008, with the UR10 following in 2012 and the tabletop UR3 appearing in 2015. Following Universal Robots’ cue, a number of other robot manufacturers have subsequently entered the cobot space, with some 40 companies advertising “cobots” by mid-2017.

Cobots according to Universal Robots

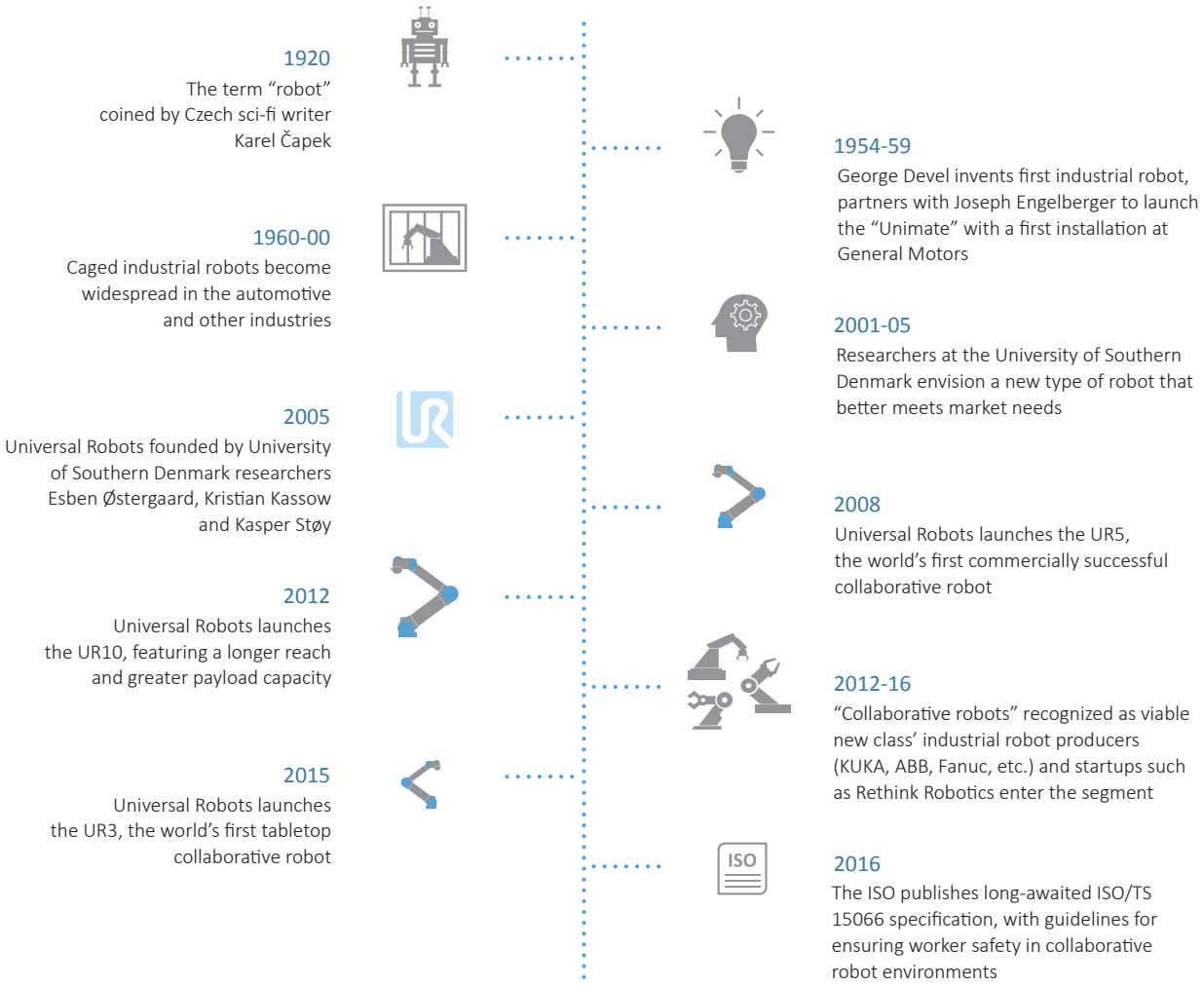
For Universal Robots, cobots are robots that:

- Comprise small-footprint robotic arms only
- Are safe for people to work with and around – no need for protective fencing
- Are easy for ordinary operators to program, deploy and re-deploy
- Serve as tools for operators, not devices that replace human workers
- Enable companies to keep control of their own automated processes

While the cobots that Universal Robots produces are sometimes deployed in fully automated environments with no human workers, they are intended primarily for collaborative use, with cobot and operator working together to complete the assigned tasks.

Universal Robots does not produce traditional industrial robots.

Timeline of cobot history



What is a *universal* robot?

The name "Universal Robots" was taken from Rossum's Universal Robots, a science fiction play by the Czech writer Karel Čapek, who actually first coined the term "robot."

At Universal Robots, we define the term as: Robots that enable different people in different countries working in different industries to automate different processes with different budgets and programming skills.[11]

Although the term does not figure widely in this White Paper, it is important to understand the concept, as it helps explain Universal Robots' unique role in the industry as well as the company's relationship to Industry 4.0 and beyond (see "Democratizing automation" below).

"Robots that enable different people in different countries working in different industries to automate different processes with different budgets and programming skills."

THE ROLE OF COBOTS IN INDUSTRY 4.0

Industry 4.0-ready

As devices, most cobots – and certainly cobots from Universal Robots – are fully compatible with Industry 4.0 design principles. Equipped with powerful onboard computers, they are interoperable and easily able to join the Internet of Things (IoT) in any factory environment. They promote information transparency via their ability to collect data and pass it on to other systems for analysis, modelling and so on. They provide technical assistance, in the sense that they "physically support humans by conducting a range of tasks that are unpleasant, too exhausting, or unsafe for their human co-workers."[12] And they are able to facilitate decentralized decisions – although cobots are normally used more as tools wielded by their operators than as autonomous entities (see "What cobots tell us about Industry 4.0" below).

In addition, cobots are classic Industry 4.0 products in that they are digital products that continue evolving through software updates and their own programmability. They even support digital (XaaS) business models, as companies like Hirebotics – which rents cobots by the hour – are proving.

Democratizing automation

Beyond their innate Industry 4.0 compatibility, cobots have played a major role in enabling companies that might not have been able to afford industrial robots to start automating their processes. Because they are versatile, easy to program, small, lightweight and affordable, cobots are being deployed at SMEs, to retrofit older factories belonging to companies that might not be in a position to build a turnkey Industry 4.0 facility, and at companies of all sizes in developing countries.

These same qualities – versatility, user-friendliness, small footprint and affordability – also make cobots eminently suitable for deployment in processes that were not previously automated. By "democratizing" robotic automation in this way, cobots help companies everywhere join the latest wave of automation, even if they are not ready to go all the way to Industry 4.0.

Cobot compliance with Industry 4.0 design principles

Design Principle	Cobot Compliance
Interoperability	Yes
Information transparency	Yes
Technical assistance	Yes
Decentralized decisions	Yes

When the lights are not out

In theory at least, the ultimate goal of Industry 4.0 is the "lights out" factory – a factory that is fully automated and requires no human presence on site. There are a few factories in operation today that come very near this ideal, including a Philips factory in the Netherlands that manufactures electric razors with no human workers except nine QA specialists deployed at the very end of the manufacturing process.[13]

Interestingly, when cobots are deployed in advanced Industry 4.0 environments, it is often at exactly the few points where human workers are required – such as at reworking stations. This is because cobots can not only receive instructions from other IoT devices and systems, but can – with the help of human operators – feed devices and systems with input deriving from operator observations, one-off change requests and so on.

The elephant in the room…

Despite the touchpoints between cobots and Industry 4.0 discussed above, there is still a proverbial elephant in the room. For while the ultimate aim of Industry 4.0 is to do away with factory workers, cobots are designed to work with humans retained intentionally on the factory floor. In short, there's no room for factory workers in Industry 4.0, while factory workers are vital to the success of environments where collaborative robots are deployed.

Under "What cobots tell us about Industry 4.0" below, we will examine this problem, highlighting what cobots do that Industry 4.0 cannot, and – we hope – revealing some of the limitations of Industry 4.0 that are sometimes overlooked in all the hype surrounding this admittedly fascinating concept.

"Factory workers are vital to the success of environments where collaborative robots are deployed."

WHAT COBOTS TELL US ABOUT INDUSTRY 4.0

Could it be that, despite Industry 4.0, man is still the measure of all things?

What are workers worth?

What are factory workers worth? To be brutally honest, not much in the worldview behind Industry 4.0. And if "factory workers" are defined as "people who perform the same mindless, repetitive and sometimes strenuous or even dangerous physical motions all day long every day," then – well – it might just be best for all parties that they are replaced by robots.

At Universal Robots, however, we believe that factory workers have all sorts of skills, insights and value-adding capabilities that robots will probably never be able to replace – no matter how sophisticated they are or may become. Robots (including cobots) are quite stupid, really. They follow instructions, and they generate data. They have no process knowledge. They have no customer knowledge. They have no experience. They have no sophisticated powers of judgement. And they have no creativity. They are nothing, really, beyond what humans tell them to be.

Human workers, on the other hand, can do all the things mentioned above that robots can't do. Because of this, a setup where human workers and robots collaborate can do much more than a setup where robots are deployed to replace human workers (see "From mass customization to mass personalization" below).

Cobots enable factories to keep process ownership and knowledge in house

Another limitation with Industry 4.0 involves the ownership of processes and the knowledge it takes to manage them. The automated systems behind Industry 4.0 environments are often designed, monitored and managed by external consultants. Yet today, the availability of process knowledge – along with proximity to markets – is displacing low-cost labor as the main criterion when companies choose their manufacturing sites.

When a company outsources the management of automated systems to outsiders, this not only costs time and money. It also saps the company of exactly the kind of human knowledge that the market now demands in a factory.

Because cobots are programmed, configured and controlled locally in the factory, companies that choose the cobot route can retain ownership over their automated processes and the valuable knowledge it takes to manage them. This results in greater operational agility and flexibility, and greater competitive power in world markets.

From mass customization to mass personalization

The internet connectivity at the core of Industry 4.0 has enabled a new trend towards mass-customized products. Just think of how cars are ordered today – the buyer is able to simply go online and create a highly personalized vehicle unlike any other car of the same make and model in the buyer's neighborhood, or even town or city.

Mass customization is good, but market research shows[14] that consumers want more. Hungry for products, services and experiences with a "human touch" that lets them express themselves, consumers want not just mass customization, but mass personalization. We see this and related trends that involve giving products and services an individualized "human touch" accelerating, and we believe that a future "Industry 5.0" will revolve around putting even more of the human touch back into products.

In fact, because human operators are right at the center of Universal Robots' "collaborative robots" concept, our technologies are already paving the way for a post-Industry 4.0 world.

CONCLUSION

The future is *collaborative*

Industry 4.0 is a fascinating development in automation, and is indeed worthy of its place in the history of the industrial revolutions that have taken place since the advent of water- and steam-powered mechanization nearly a century ago. It is impossible to separate the birth of cobots from the evolution of robots in general and of robotic automation in particular. Because of this, cobots share a history and many ideas with the whole universe that the term Industry 4.0 is currently used to cover.

Still, the fundamental collaborative nature of cobots – the fact that they are designed to collaborate with human operators instead of eschewing workers the way that Industry 4.0 would – places cobots somehow outside, if not diametrically opposed to, the Industry 4.0 worldview. In our opinion, this difference – the cobot difference – exposes some significant limitations to the concept of Industry 4.0, and at least points to something beyond it. Something that Universal Robots, playfully for now, likes to call Industry 5.0.

LEARN MORE

To find out more about Universal Robots, cobots and how cobots can benefit Industry 4.0 environments and beyond

Visit www.universal-robots.com or contact esben@universal-robots.com

NOTES

1) *"Industrie 4.0", German Federal Ministry of Education and Research, accessed June 1, 2017, https://www.bmbf.de/de/zukunftsprojekt-industrie-4-0-848.html*

2) *"Forth Industrial Revolution", Wikipedia, last modified 27 May 2017, https://en.wikipedia.org/wiki/Fourth_Industrial_Revolution*

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4) *Christoph Roser ,"A Critical Look at Industry 4.0", AllAboutLean.com, December 29, 2015, accessed June1, 2017, http://www.allaboutlean.com/?s=A+Critical+Look+at+Industry+4.0*

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7) *Mario Hermann, Tobias Pentek, Boris Otto, "Design Principles for Industrie 4.0 Scenarios", 2016 49th Hawaii International Conference on System Sciences (HICSS), vol. 00, no. , pp. 3928-3937, 2016*

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12) *Mario Hermann, Tobias Pentek, Boris Otto, "Design Principles for Industrie 4.0 Scenarios", 2016 49th Hawaii International Conference on System Sciences (HICSS), vol. 00, no. , pp. 3928-3937, 2016*

13) *John Markoff , "Where's My Robot?" . Techonomy, November 12, 2012, accessed June1, 2017, http://techonomy.com/conf/12-tucson/future-of-work/wheres-my-robot/ (see transcript)*

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